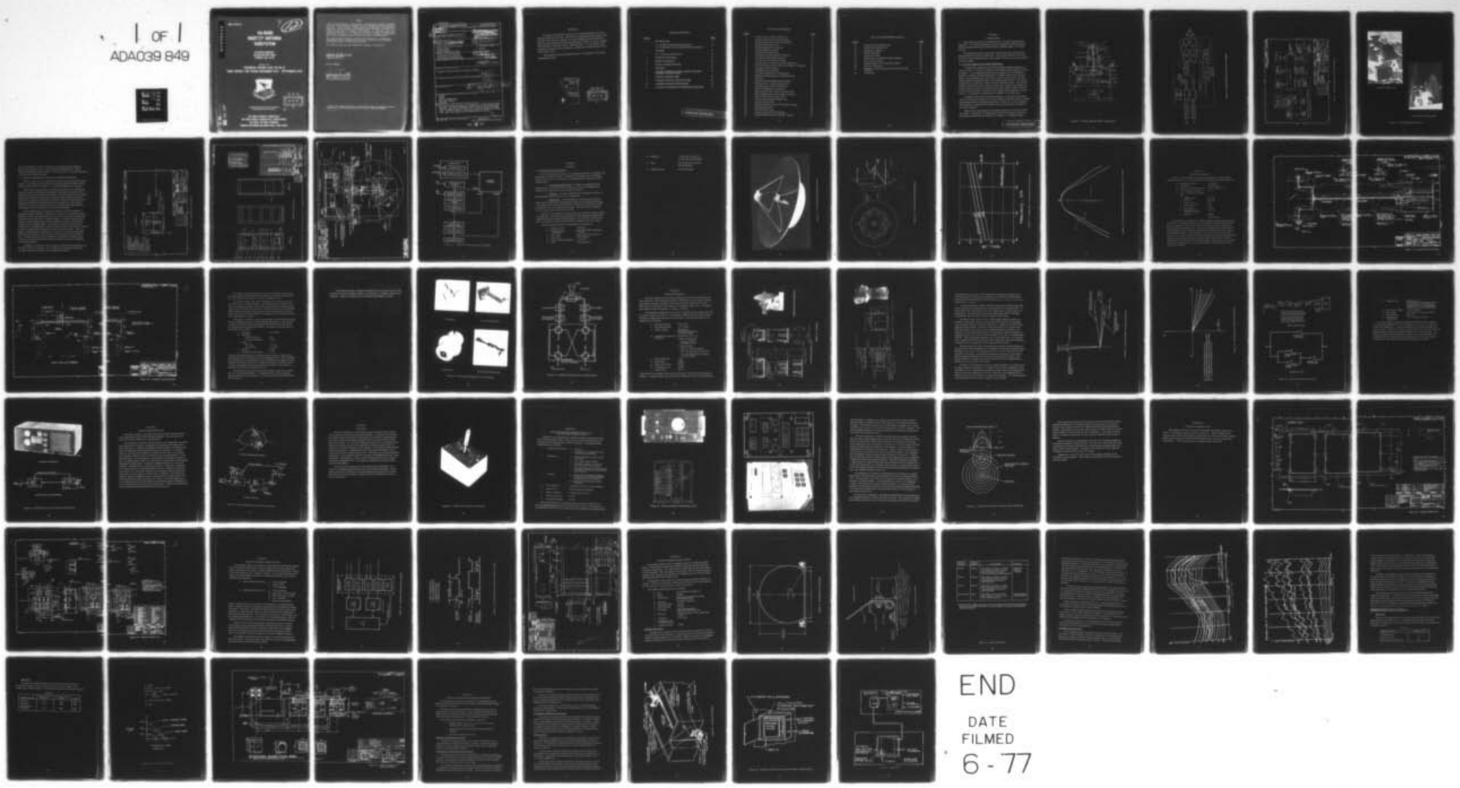
AD-A039 849 RAYTHEON CO WAYLAND MASS F/G 9/5

KA-BAND ROOFTOP ANTENNA SUBSYSTEM.(U)

JAN 77 E M PERDUE, T F JOYCE F33615-74-C-4012

UNCLASSIFIED ER76-4103 AFAL-TR-76-27 NL

1 OF 1
ADA039 849



END
DATE
FILMED
6-77

AFAL-TR-76-27

KA-BAND ROOFTOP ANTENNA SUBSYSTEM

RAYTHEON COMPANY
528 BOSTON POST ROAD
SUDBURY, MA. 01778

JANUARY 1977

TECHNICAL REPORT AFAL-TR-76-27
FINAL REPORT FOR PERIOD NOVEMBER 1973 - SEPTEMBER 1975

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

AIR FORCE AVIONICS LABORATORY
AIR FORCE WRIGHT AERONATICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Office of Information and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

Thaddeus A. Grizinski

THADDEUS A. GRIZINSKI
Project Engineer

FOR THE COMMANDER

James D. Everett

JAMES D. EVERETT, Lt Col, USAF
Chief, System Avionics Division
Air Force Avionics Laboratory

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: (14) (18) AFAL-TR-76-27
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): (6) KA-BAND ROOFTOP ANTENNA SUBSYSTEM.
5. TYPE OF REPORT & PERIOD COVERED: (9) ~~Final Technical Report, Nov 1973 - Sep 1975~~
6. PERFORMING ORG. REPORT NUMBER: (14) ER76-4103
7. AUTHOR(s): (10) Edward M. Perdue ~~Raytheon Company~~, Thomas F. Joyce ~~Raytheon Company~~
8. CONTRACT OR GRANT NUMBER(s): (15) F33615-74-C-4012
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Raytheon Company, Boston Post Road, Wayland, Massachusetts 01778
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 12272202
11. CONTROLLING OFFICE NAME AND ADDRESS: System Avionics Division (AA), Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio 45433
12. REPORT DATE: (11) January 1977
13. NUMBER OF PAGES: (12) 80p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited.

(16) 1227

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(17) 22

18. SUPPLEMENTARY NOTES

(9) Final technical rept. 1 Nov 73 - 30 Sep 75

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

KA-BAND
Antenna
Satellite Communication
Extra High Frequency
Microwave

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The technical report documents the development of a Ka-Band Rooftop Antenna Subsystem. The antenna subsystem is used in conjunction with the Ka-Band Satellite Communications Set AN/ASC-22 RF terminal and Digital Data Modem Group. The report contains a review and discussion of the design decisions, trade studies and problem areas encountered during the design.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

298 350 88

PREFACE

The work covered in this report was accomplished under Air Force Contract F33615-74-C-4012. This effort is documented under Project 1227, Task 22, Work Unit 02, entitled "Nine Foot Rooftop Antenna Subsystem." The work was administered under the direction of Bruce L. Noren, Captain, USAF; Robert L. Wasson, Major, USAF; and Mr. T.A. Grizinski in that sequence, from the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio.

This report covers work performed from 1 November 1973 through 30 September 1975.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

SECTION 1

INTRODUCTION

This report documents the development of a Ka-Band Rooftop Antenna Subsystem. This antenna subsystem is used in conjunction with the Ka-Band Sattelite Communications Set AN/ASC which is installed within a C-135 type aircraft.

The following sections of this report will describe the overall Rooftop Antenna Subsystem and each subdivision. This section contains a review and discussion of the design decisions, trade studies and problem areas encountered during the design.

1.0 KA-BAND ROOFTOP ANTENNA SUBSYSTEM

A configuration diagram of the Ka-Band Rooftop Antenna Subsystem is shown in Figure 1, and a block diagram of the Rooftop Antenna System is shown in Figure 2. The Rooftop Antenna Subsystem consists of a 10 foot diameter antenna, a pedestal and drive mechanism, associated rotary joints and waveguide, antenna position control/power unit, secant correction unit, joystick, remote control and indicator panel, and computer interface unit. The antenna and pedestal are located in a radome atop the equipment shelter. The antenna position control/power unit, secant correction unit, joystick, and remote control and indicator panel are mounted in the console inside the shelter adjacent to the Ka-Band terminal. The PDP 11/45 computer control interface unit and the DR 11-C interface are located below the shelter in the CSEL area.

In addition to the above mentioned equipment, the Ka-Band transmitter-receiver terminal will occupy a part of the shelter and interface with the Rooftop Antenna Subsystem via waveguide connections. Figure 3 is a interconnection block diagram, including the distribution box where all signals are routed to the proper locations.

Figure 4(a) is a photograph of the Rooftop Antenna as viewed from above the radome. Figure 4(b) is a photograph of the 10 foot diameter antenna and the pedestal mount before the radome was installed. The deflated radome

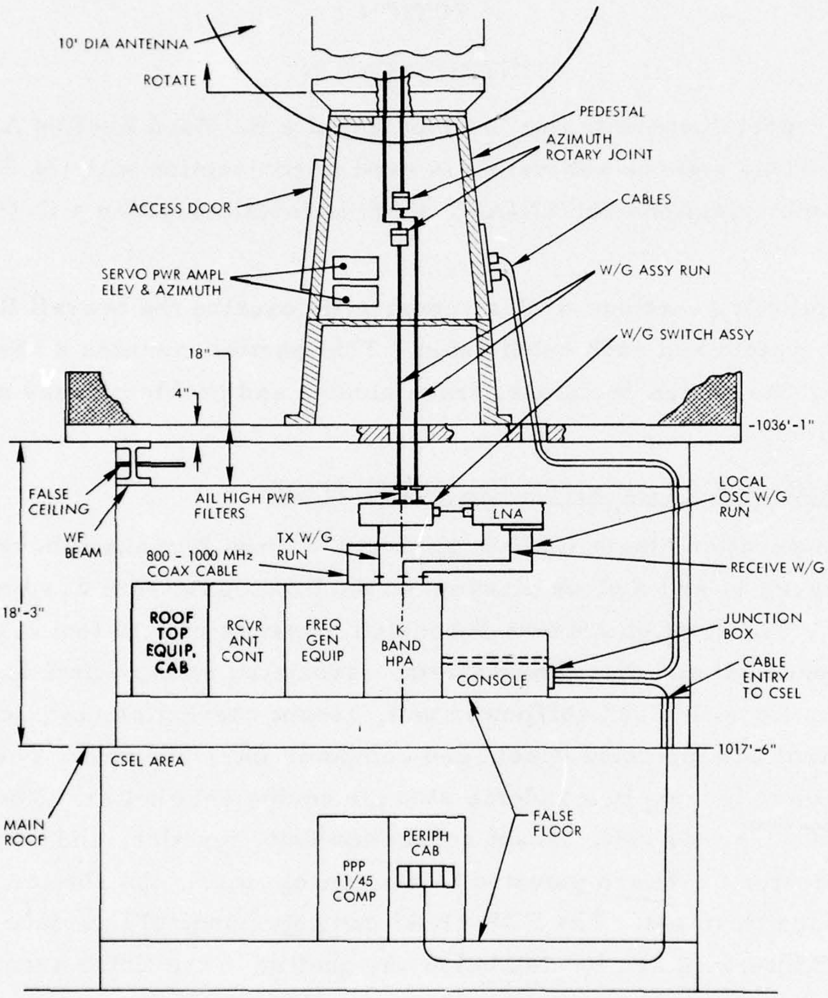


Figure 1. Rooftop Antenna/CSEL Configuration

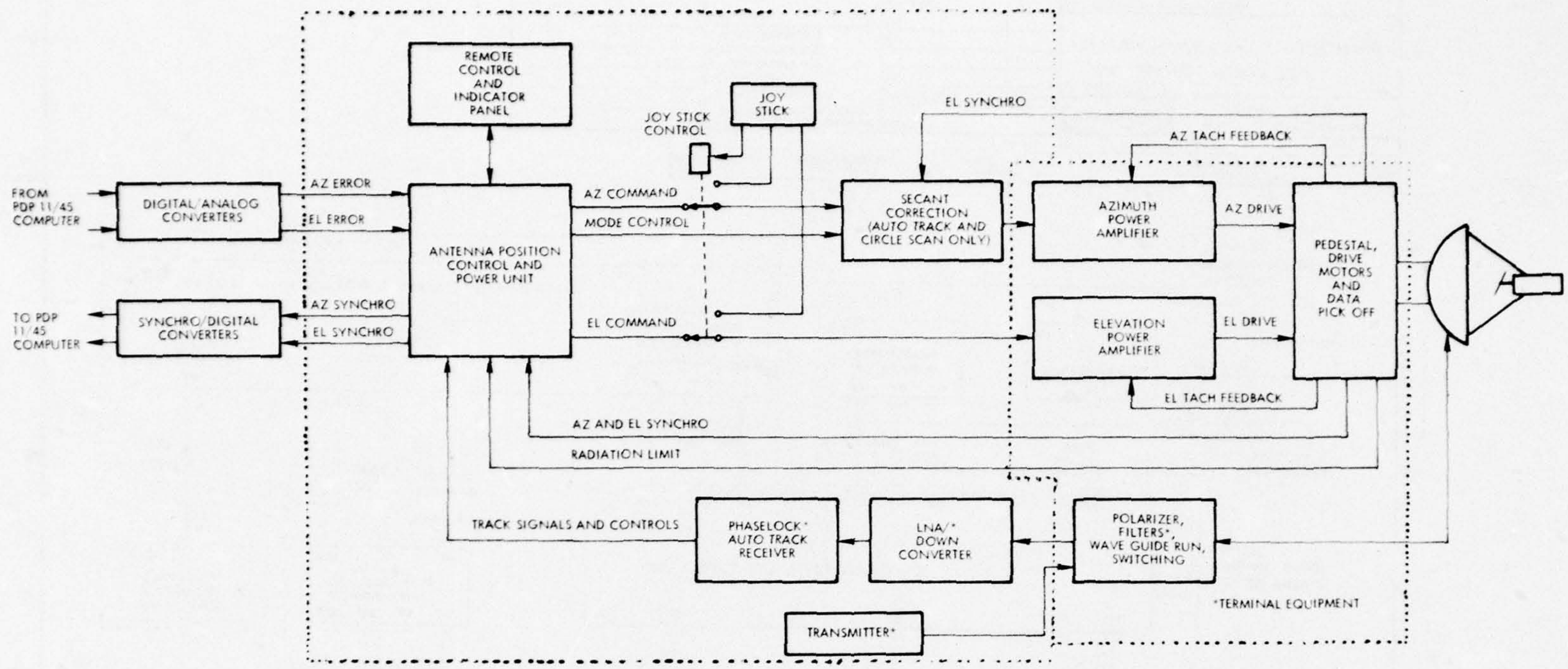


Figure 2. Rooftop Antenna System Block Diagram

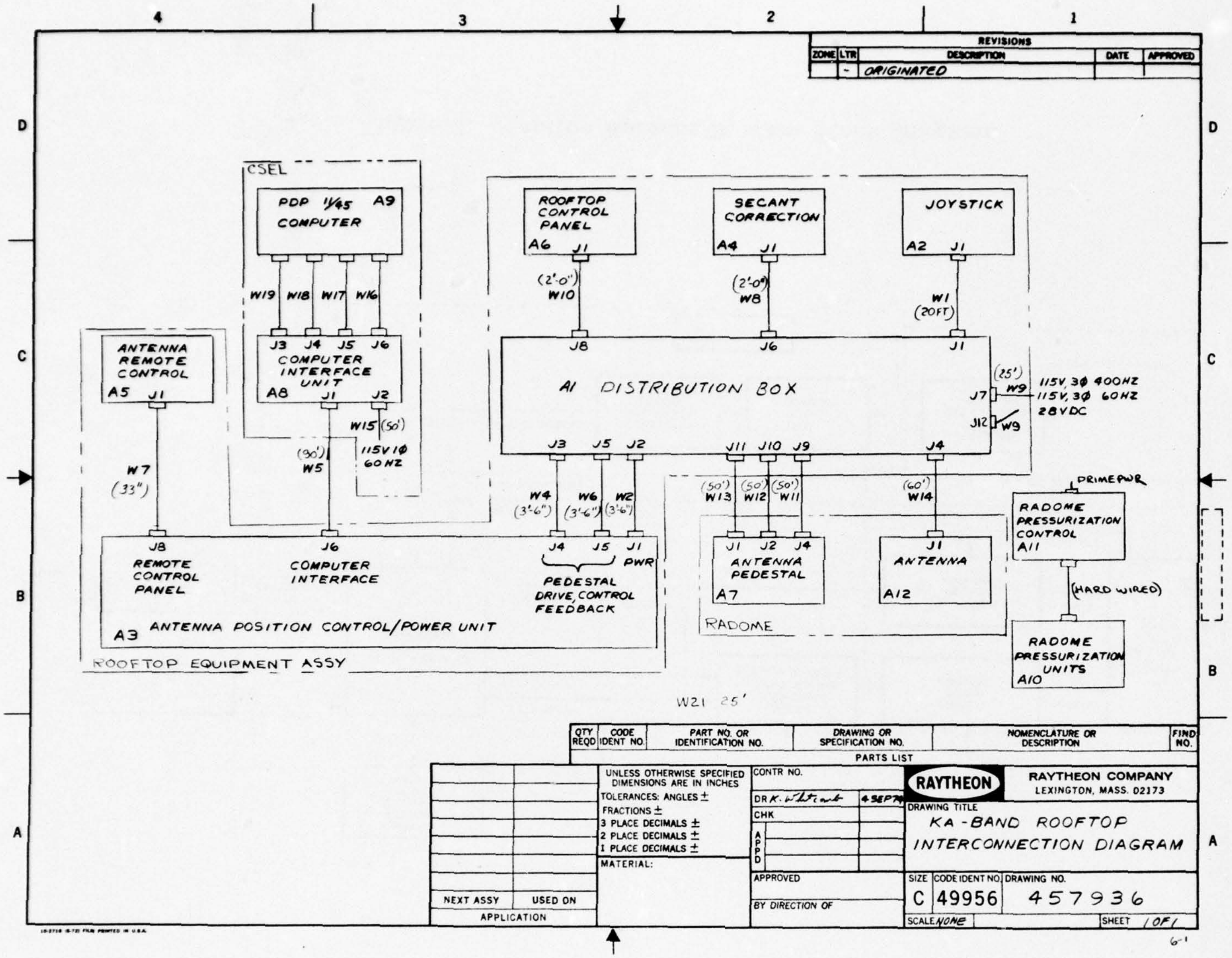
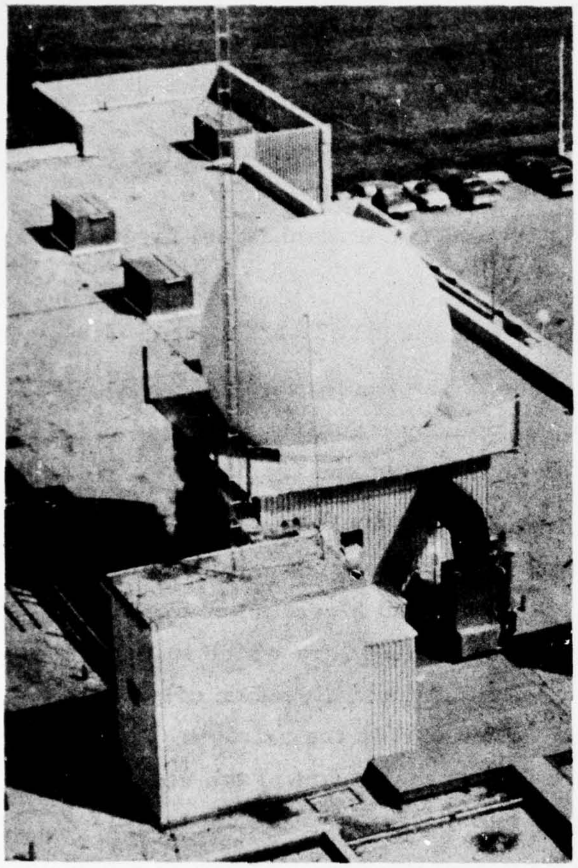


Figure 3. Ka-Band Rooftop Interconnection Diagram



(a) ROOF TOP INSTALLATION

(b) ANTENNA AND PEDESTAL MOUNT

Figure 4. Rooftop Antenna Subsystem

is in the background. Figure 5 illustrates the Rooftop Control Equipment Room with the different units of the Rooftop Antenna Subsystem. Figure 6 shows the Rooftop Equipment Cabinet. Finally, Figure 7 is a mechanical layout of the Rooftop Antenna subsystem.

1.1 DETAILED DISCUSSION OF ROOFTOP ANTENNA SUBSYSTEM

Refer to Figure 2 for the following discussion of the Rooftop Antenna Subsystem. This system has the capability of manual pointing, automatic closed loop tracking of LES 8/9 satellites, or computer designation and tracking.

There are two manual modes of pointing the antenna; (1) by pressing the switch on top of the joystick thereby placing control at the joystick and (2) by trim pots located on the remote control panel. Azimuth and elevation command signals from either unit control their respective power amplifiers which in turn drive the antenna in the direction required. Azimuth and elevation drive channels are identical except for the secant correction unit in the azimuth channel. The gain in the azimuth must be corrected by the secant of the elevation angle in order to maintain a constant drive sensitivity.

In the tracking mode, the antenna is slewed to within one degree of a designated position manually. The spatial acquisition is then started whereby, through a circular scan search pattern, the receiver uses a peak seeking technique to detect the presence of a received signal. During this spatial search period, a fast frequency search also takes place to overcome the frequency uncertainty due to Doppler shift. After spatial acquisition is achieved, the antenna scan is stopped and the receiver initiates a closed-loop frequency search in order to finally achieve phase-lock in the auto-track receiver. Upon completion of this operation, the antenna is in the active tracking mode utilizing conical scanning and the receiver issues a discrete signal indicating phase-lock. Figure 8 shows how the entire terminal including the Rooftop antenna subsystem and Ka-Band terminal interface in order to execute an acquisition and tracking operation.

In addition, an interface exist between the rooftop antenna subsystem and the CSEL PDP 11/45 computer. The computer gives pointing designation to the antenna position control unit for controlling the antenna.

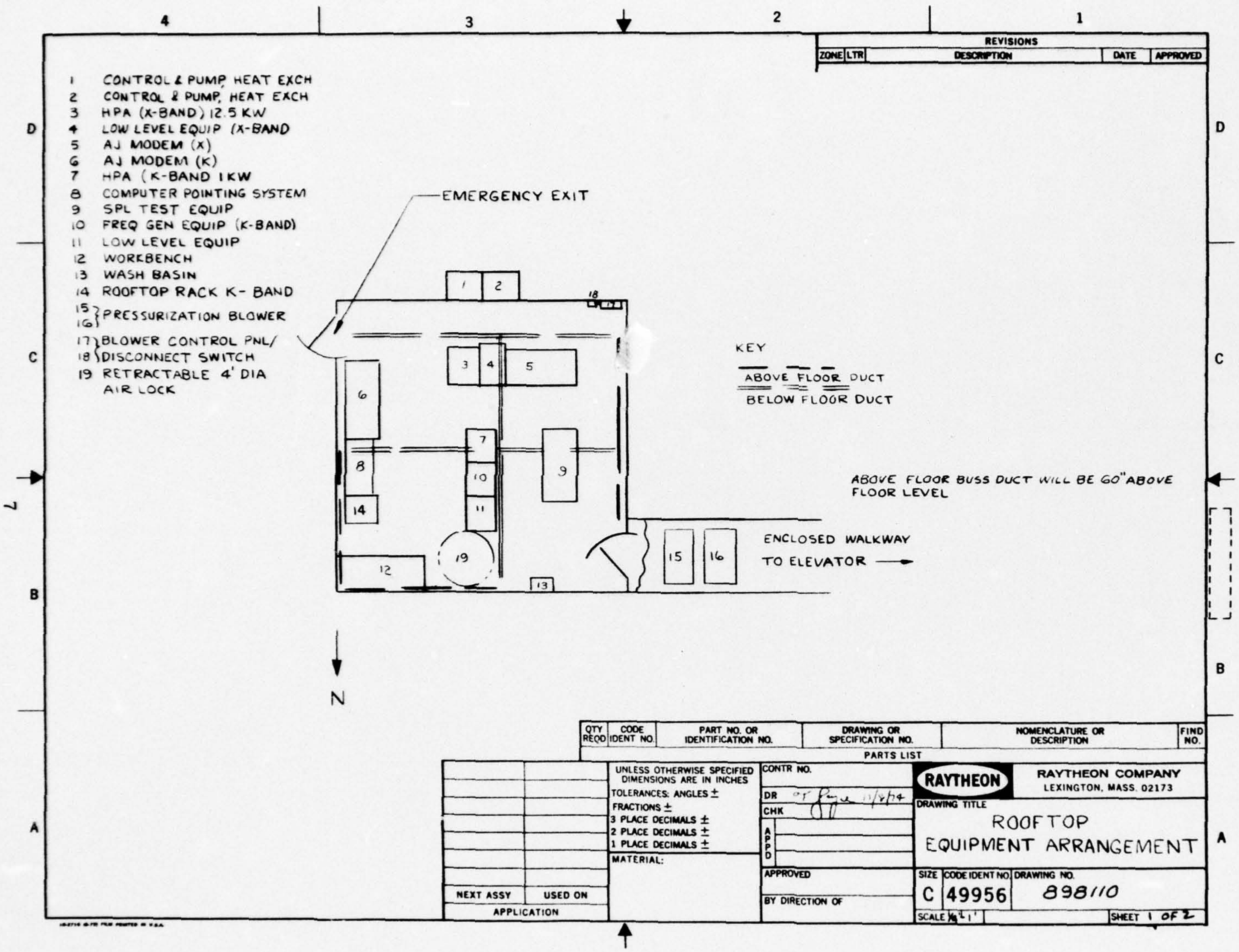
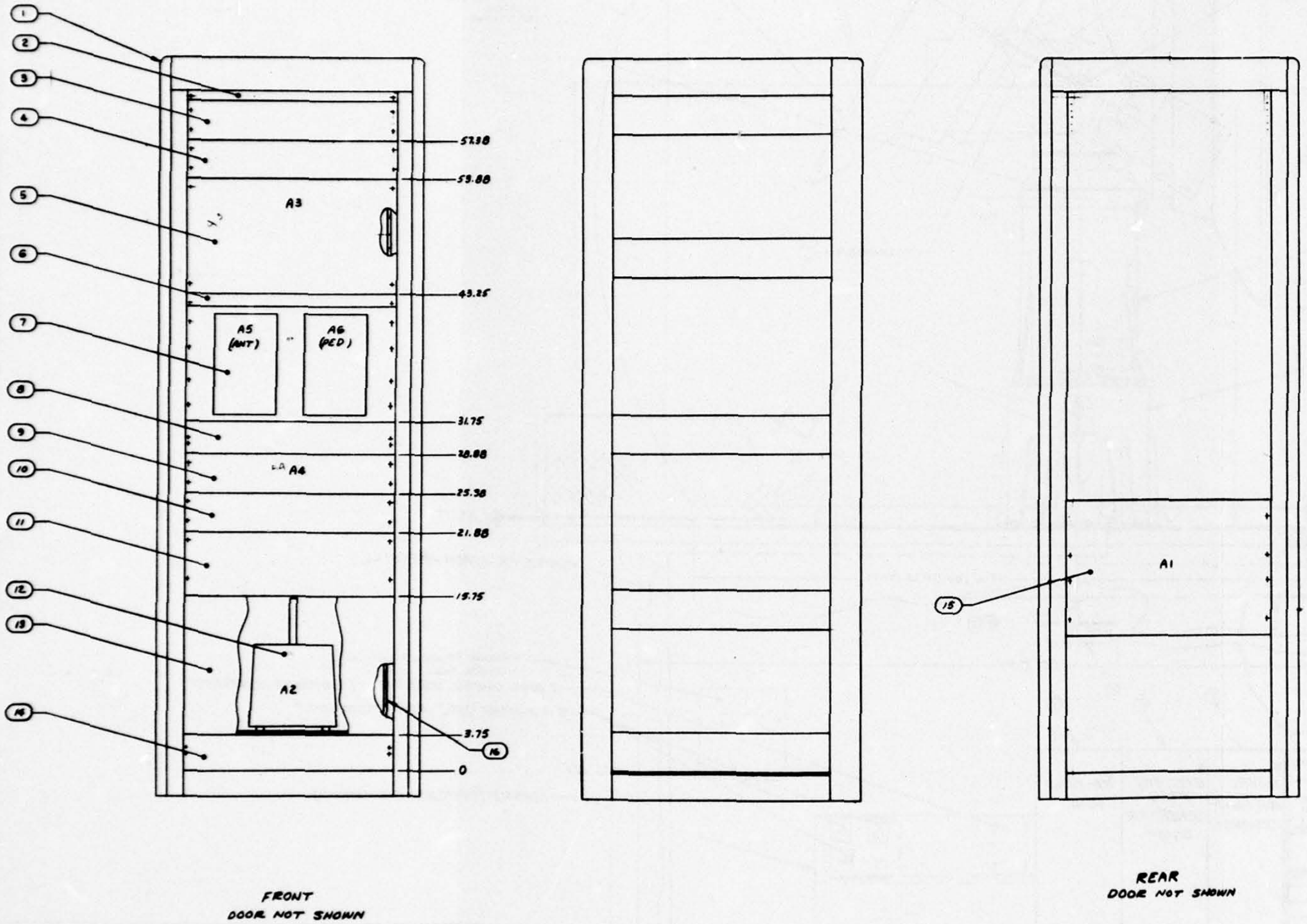


Figure 5. Rooftop Equipment Arrangement



NOTES
1. FOR CABLE TERMINATIONS SEE DWG NO. 898110

CABLE CONNECTIONS			
CABLE	DESTINATION FROM	DESTINATION TO	FIND NO
W1	A2J1	A1J1	17
W2	A3J1	A1J2	18
W4	A3J4	A1J3	19
W6	A3J5	A1J5	20
W7	A3J8	A5J1	21
W8	A4J1	A1J6	22
W10	A6J1	A1J8	23
W5	A3J6	A8J1	24
W9	PRIME PWR	A1J1 A1J12	25
W11	A1J9	A7J4	26
W12	A1J10	A7J2	27
W13	A1J11	A7J1	28
W14	A1J4	A12J1	29
W15		A8J2	30
W16			31
W17			32
W18			33
W19			34
W20			35
W21			36

QTY REQD	CODE IDENT NO.	PART NO. OR IDENTIFICATION NO.	DRAWING OR SPECIFICATION NO.	NOMENCLATURE OR DESCRIPTION	FIND NO.
				CABLE ASSY W21	36
				W20	35
				W19	34
				W18	33
				W17	32
				W16	31
1		898094		W15	30
1		898093		W14	29
1		898092		W13	28
1		898091		W12	27
1		898090		W11	26
1		898088		W9	25
1		898084		W5	24
1		898089		W10	23
1		898087		W8	22
1		898086		W7	21
1		898085		W6	20
1		898083		W4	19
1		898082		W2	18
1		898081		CABLE ASSY W1	17
4		D600-5-20	CHASSIS TRAK	SLIDE	16
1		457957		ROOFTOP DISTRIBUTION UNIT	15
1				PANEL BLANK	14
1				DRAWER	13
1		28378	SCIENTIFIC ATLANTA	JOYSTICK MODEL 3721	12
1				PANEL BLANK	11
REF				AGE UP LINK RCVR	10
1		131803	SCIENTIFIC ATLANTA	SECANT CORRECTION UNIT	9
1				PANEL BLANK	8
1		457964		ROOFTOP CONTROL UNIT	7
1				PANEL BLANK	6
1			BELL	ANTENNA POSITION CONTROL	5
1		457890		DOPPLER SIMULATOR	4
1		457891		ANTENNA SCAN SIM	3
1				PANEL BLANK	2
1				RACK	1

PARTS LIST

RAYTHEON
RAYTHEON COMPANY
LEXINGTON, MASS. 02173

ROOFTOP
EQUIPMENT CABINET

E 49956 898096

Figure 6. Rooftop Equipment Cabinet

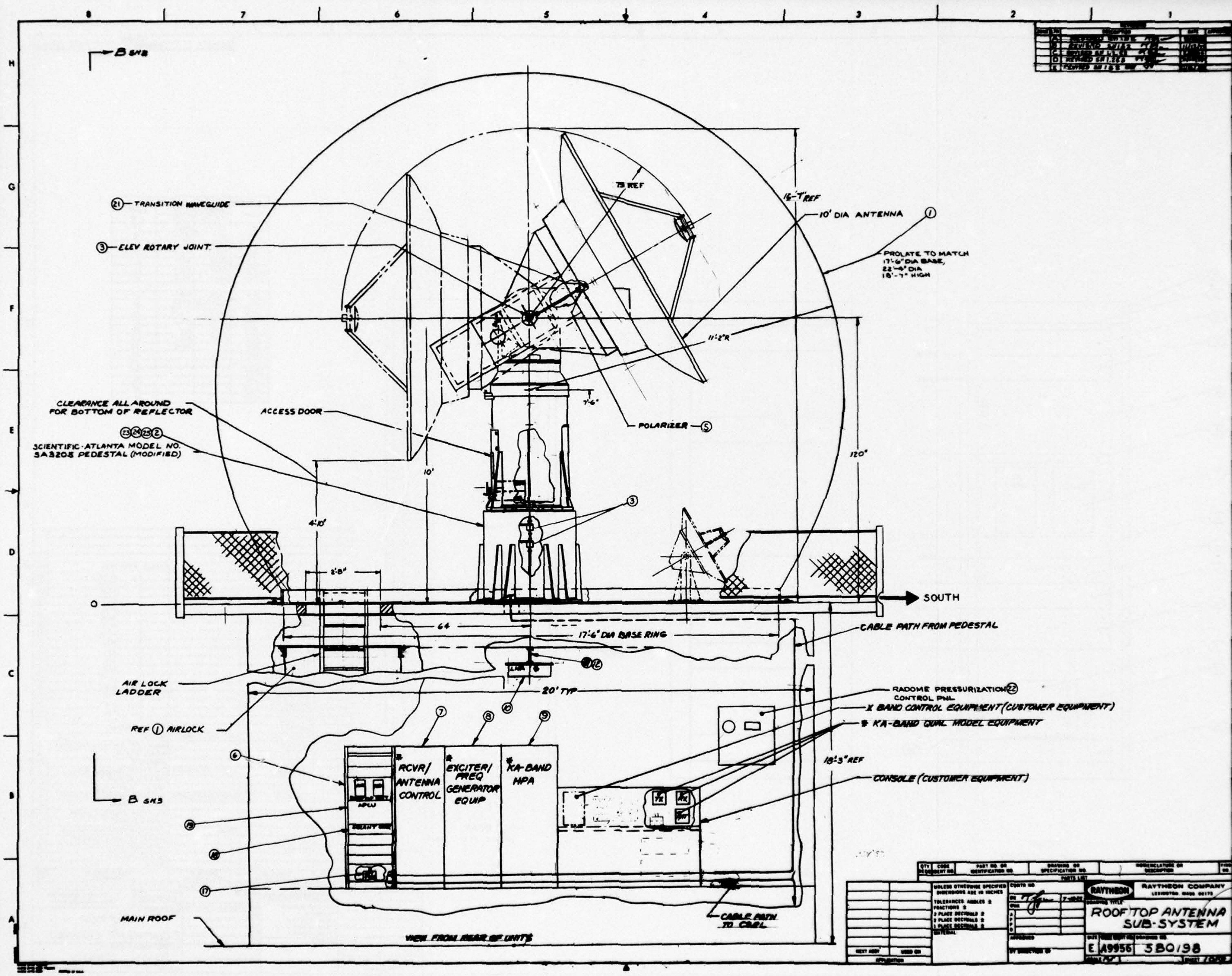


Figure 7. Rooftop Antenna Subsystem

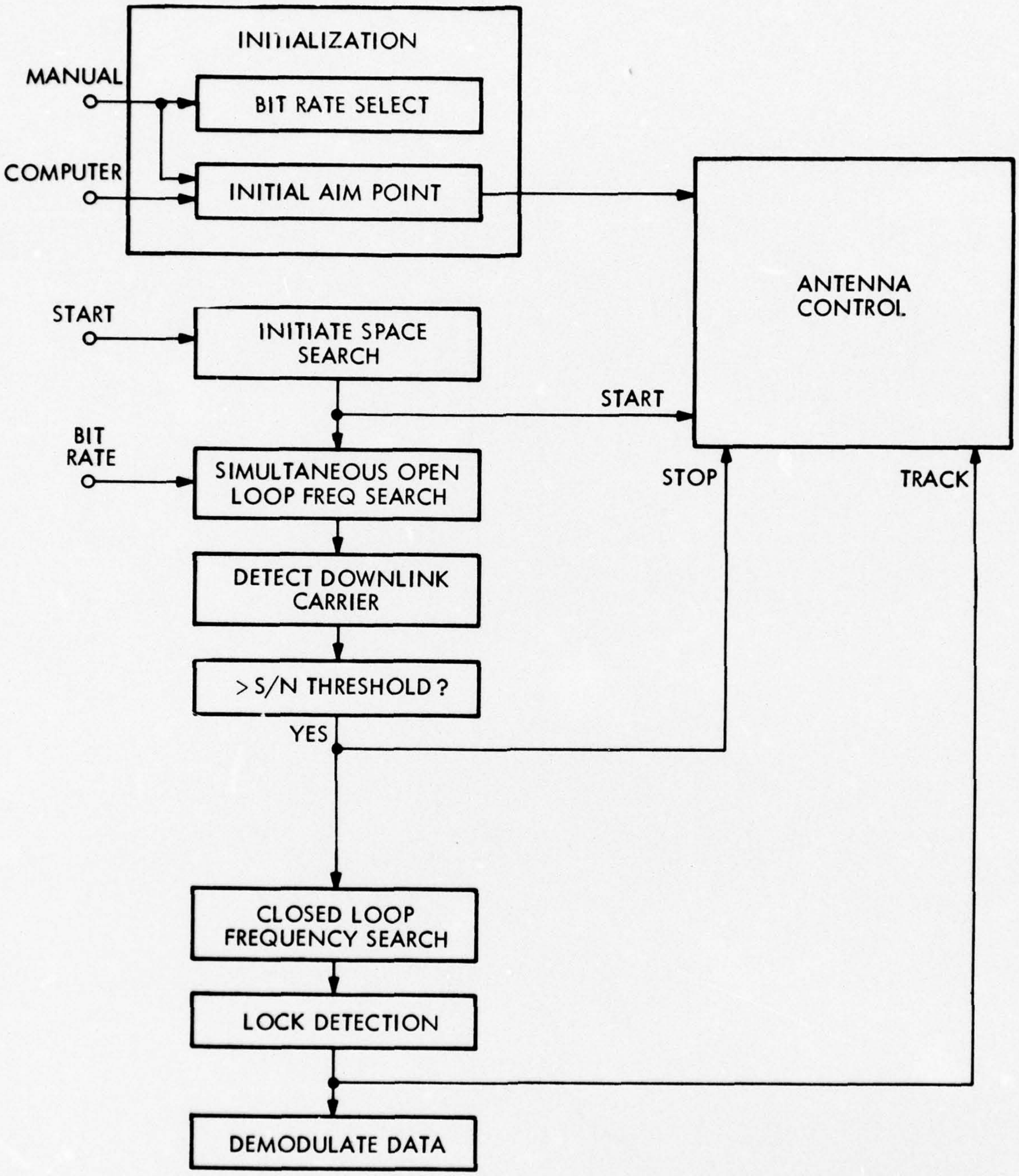


Figure 8. Acquisition and Tracking Flow Diagram

SECTION 2

ANTENNA

2.0 10 FOOT KA-BAND ANTENNA

The 10-foot Ka-Band antenna is of a cassegrain structure, resulting in an antenna gain of 58 dB minimum. The antenna can operate over a frequency range of 34 to 40 GHz. The antenna is a single assembly consisting of three subassemblies:

a. Circular waveguide feed - RF signal is propagated in both directions (Receive and Transmit) in a piece of circular waveguide that is centered at the focal point of the cassegrain structure.

b. Reflector - The main reflector in the cassegrain structure is the paraboloidal section and is 10 feet in diameter.

c. Subreflector - The subreflector is constructed as part of a motor subassembly and is a hyperbolical section of the cassegrain structure. The function of the motor subassembly is to nutate the subreflector at a rate of about 65 Hz for the conical scan tracking. The squint angle is adjusted for a crossover loss of about 0.4 to 0.7 dB.

Figure 9 and 10 illustrate the structure of the cassegrain antenna and the rf energy path. The antenna is mounted on the GFE pedestal by means of the reflector mount and counterweight structure. The rf feed line consist of circular waveguide (0.328 inch inside diameter) operating in the TE_{11} mode.

The antenna performances characteristics are as follows:

a.	Frequency band	34-40 GHz
b.	Transmit/Receive Polarization	Both right-hand and left-hand circular
c.	Beam shape	Symmetrical (see Figure 9)
d.	Axial ratio	2 dB maximum
e.	Power handling capability	1.5 kW CW
f.	VSWR	1.5:1 maximum

g.	Sidelobes	-16 dB from 0° to $\pm 10^{\circ}$ -30 dB from $\pm 10^{\circ}$ to $\pm 180^{\circ}$
h.	Gain	59 dB goal (see Figure 8) 59 dB minimum
i.	Reflector Size	10 Foot Diameter

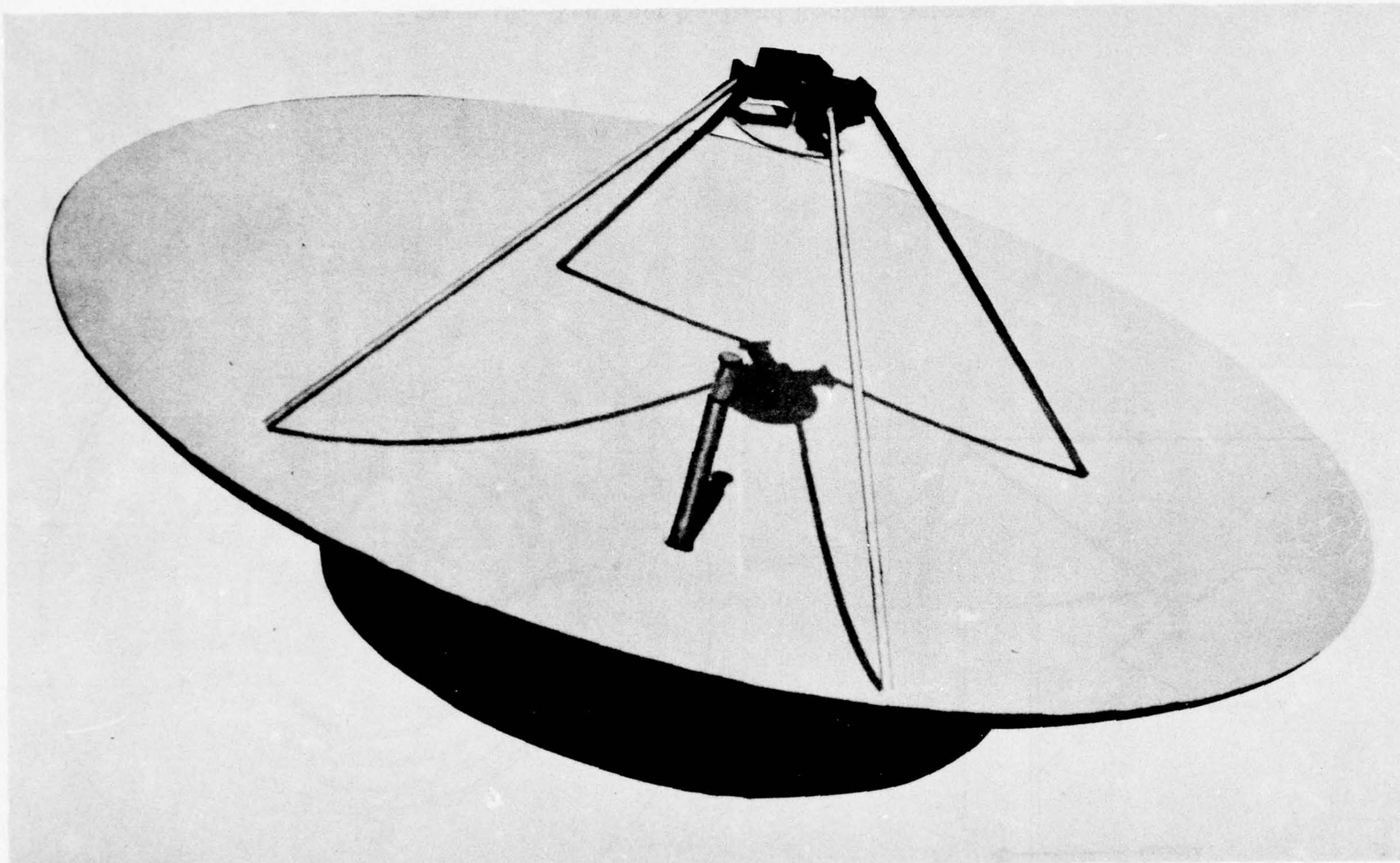


Figure 9. Ten Foot Ka-Band Rooftop Antenna

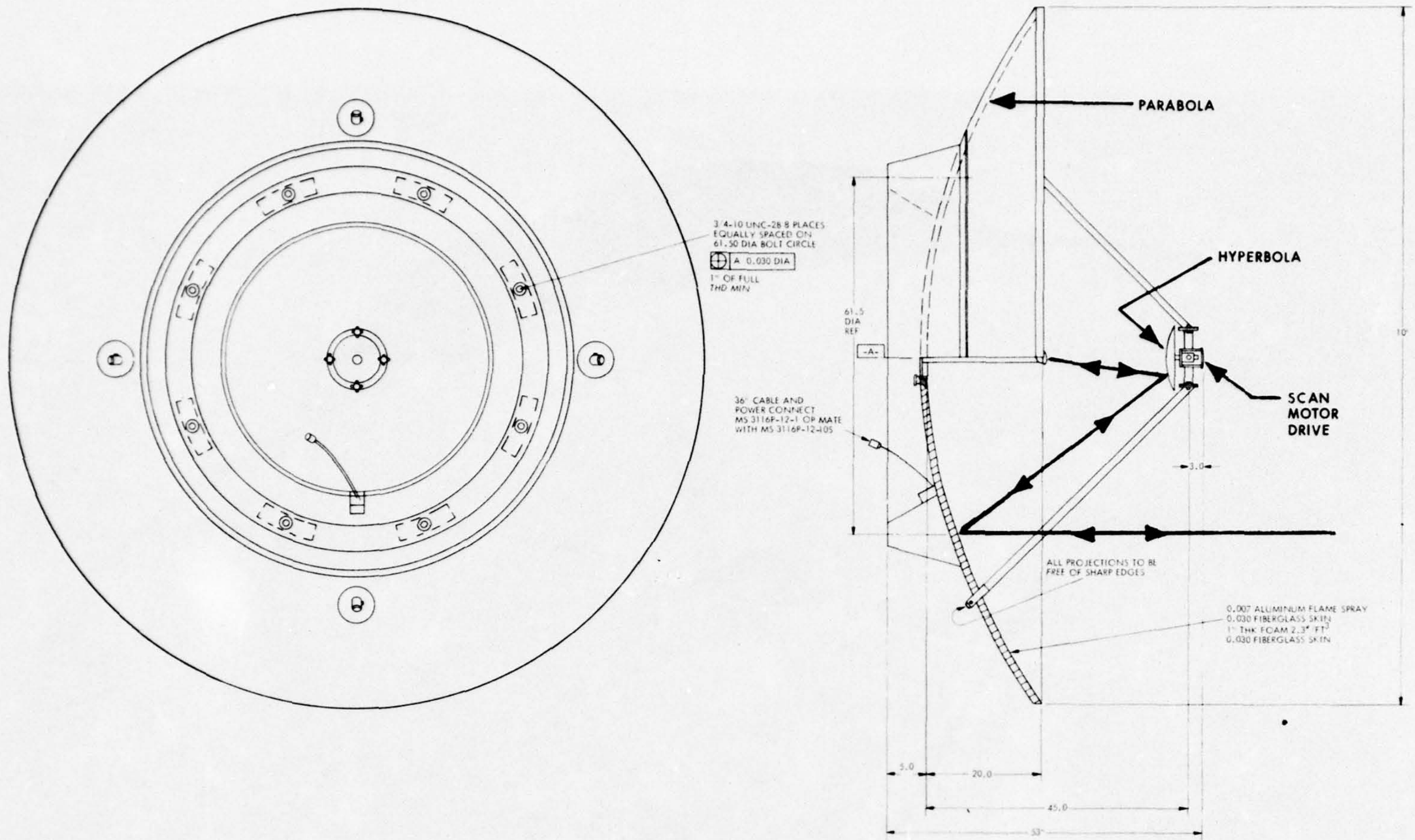


Figure 10. Ten Foot Ka-Band Rooftop Antenna

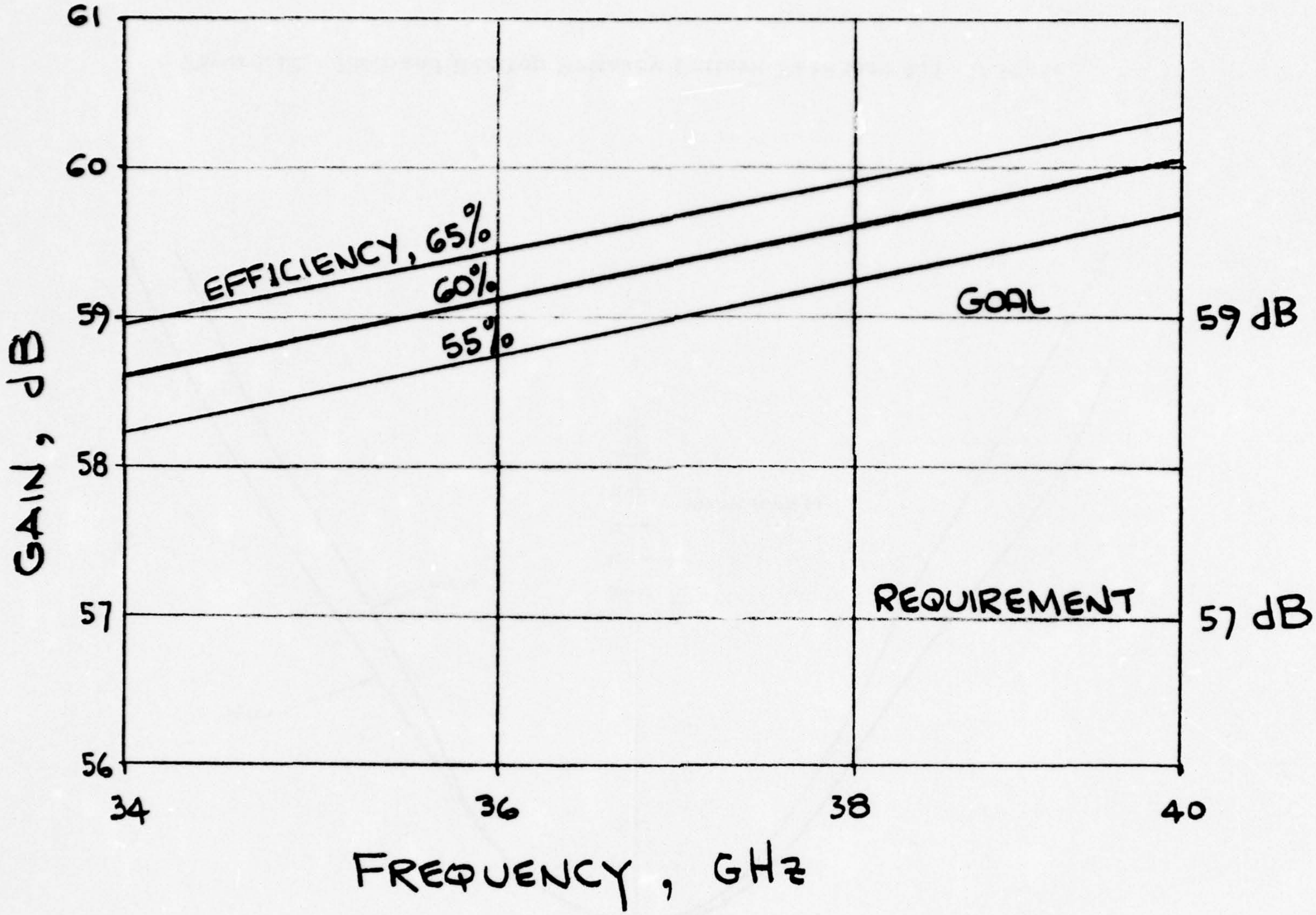


Figure 11. Antenna Gain vs Frequency (10 Foot Diameter)

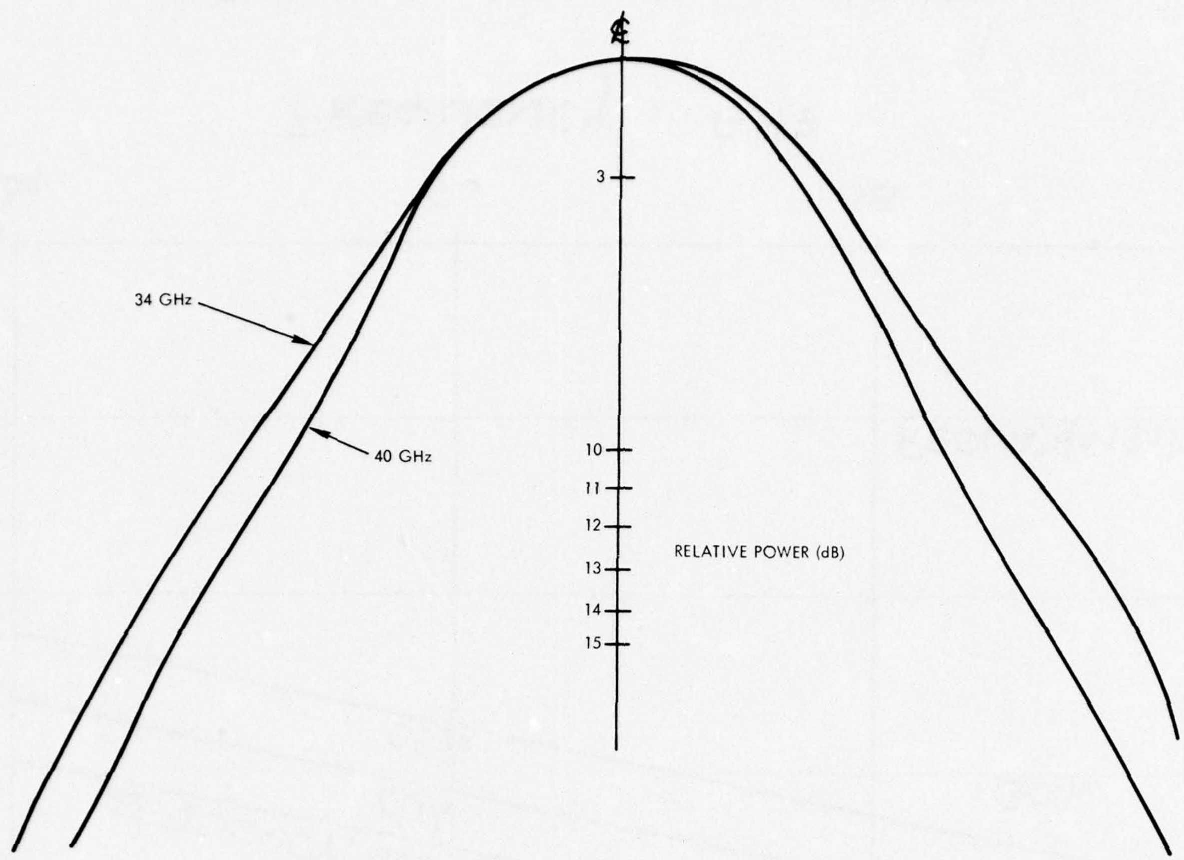


Figure 12. Ka-Band Rooftop Primary Pattern Feedhorn 411 • H Plane

SECTION 3

ROOFTOP WAVEGUIDE

Figures 13 and 14 illustrate the waveguide configuration for the Rooftop Antenna Subsystem. The rf characteristics of the waveguide runs are as follows:

a.	Operating Frequency	34-40 GHz
b.	Polarization	RHP and LHP
c.	Axial Ratio (Including Antenna)	2.0 dB (VSWR ≤ 1.5)
d.	VSWR (Including Antenna)	≤ 1.5
e.	Loss - Feed Part to Pedestal base	

1.	Multiple Bend	0.25 dB
2.	90° Bend	0.06 dB
3.	Rotary Joint EL	0.25
4.	Rotary Joint AZ	0.25
5.	Six Flanges	0.30
6.	Straight Sections 15 feet at 0.2 dB/ft	3.00 dB
7.	Polarizer	0.40
		4.51 dB Total

The antenna feed is followed by circular waveguide to the polarizer as shown in Figure 14. Following the polarizer, all waveguide is WR-28 rectangular waveguide. It includes two lines, each with two in-line single-channel rotary joints for azimuth and elevation rotation. The base of the waveguide run interfaces with the Ail high power filters and the waveguide switch assembly which make up part of the diplexing system. The feed (Figure 15a) is a simple conical horn with an aperture of 1.5 inches followed by circular waveguide of 0.328 inch inside diameter. The 0.328 inch diameter waveguide section is flange-mounted to the reflector mounting hub and is terminated on the pedestal side of the reflector. An aluminum cone is used to position the feed and provide adequate support during both static and dynamic conditions.

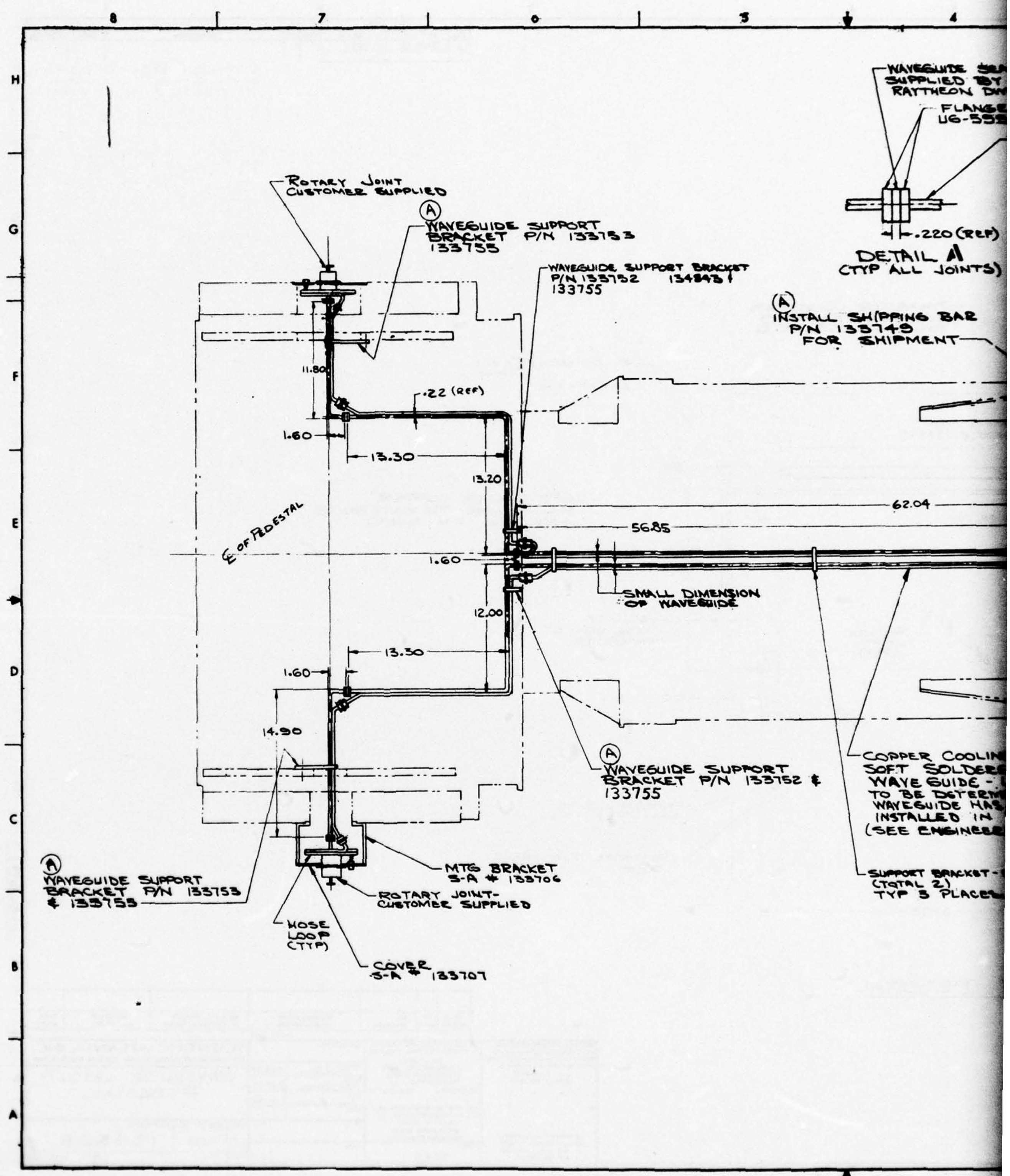


Figure 14. Waveguide Layout Drawing

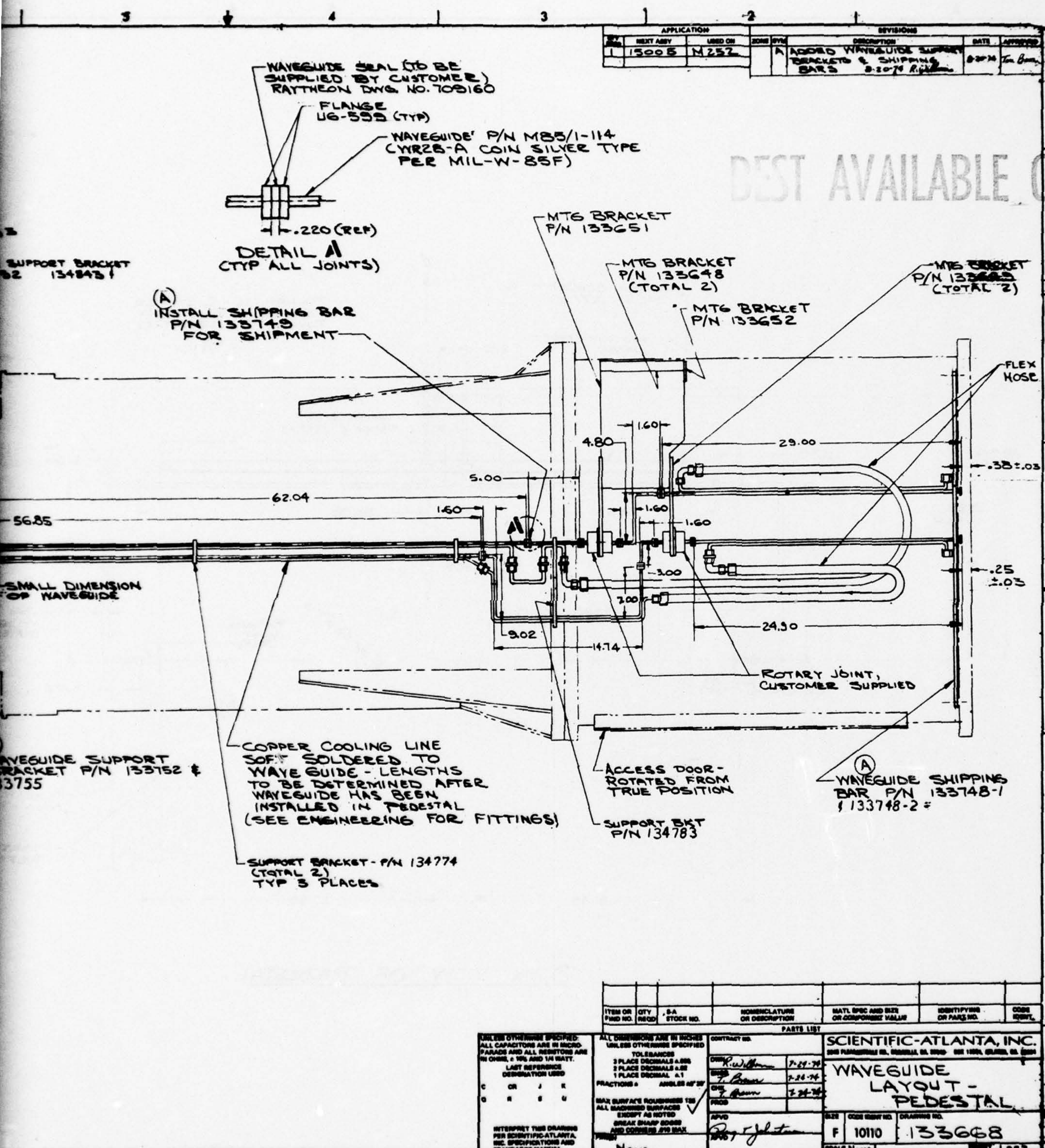
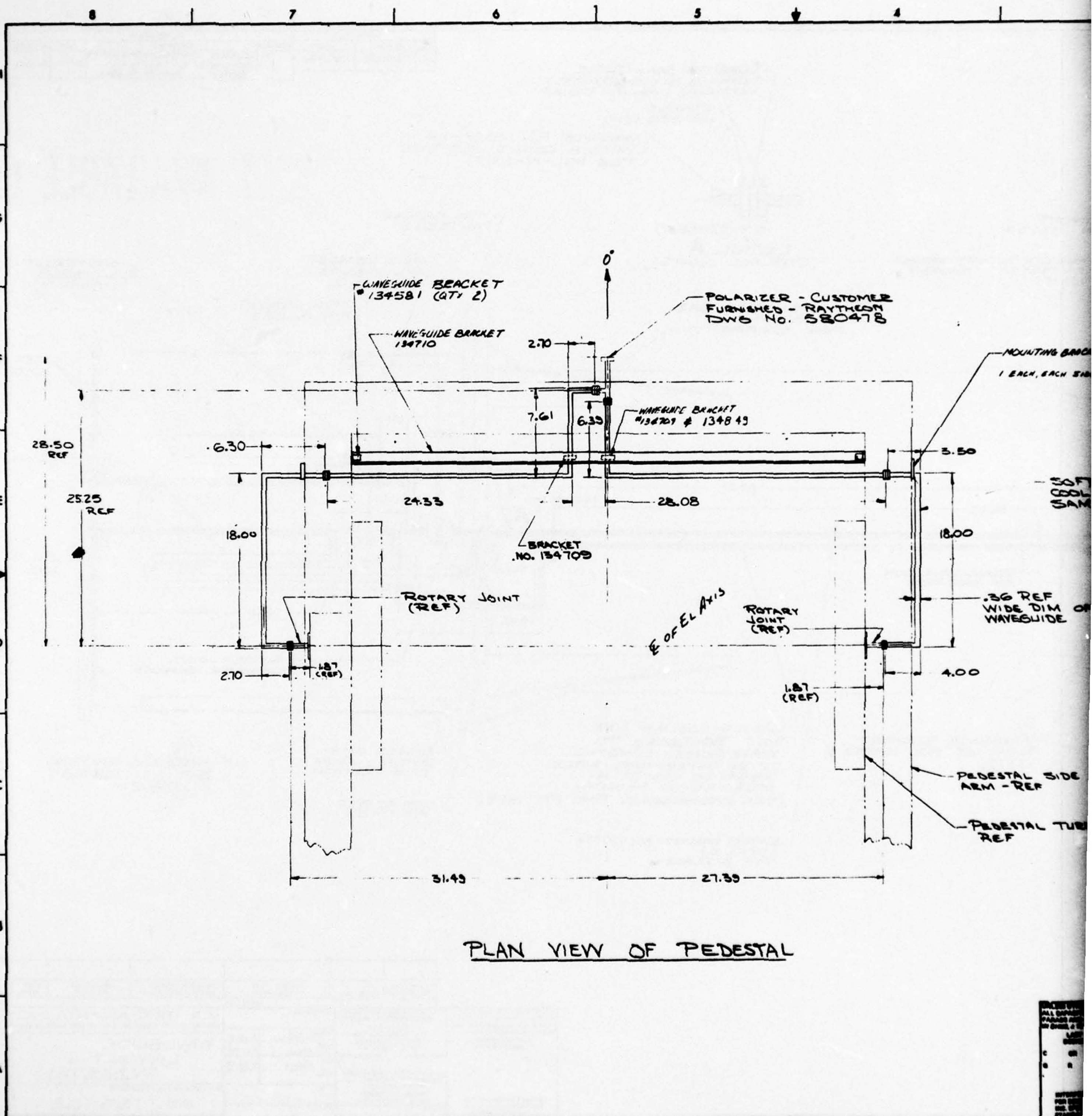


Figure 13. Waveguide Layout Pedestal



PLAN VIEW OF PEDESTAL

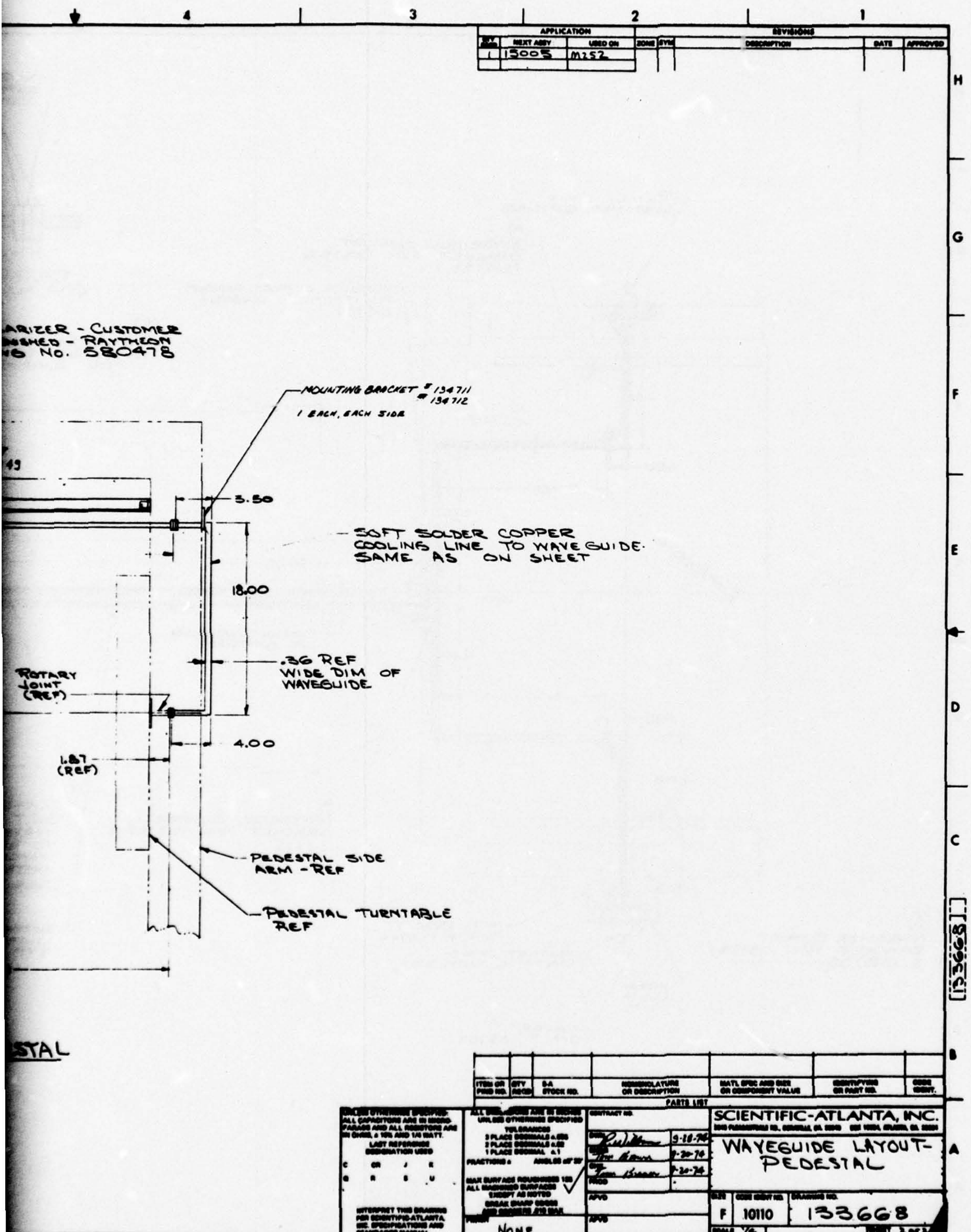


Figure 14. Waveguide Layout Pedestal

The antenna subsystem requires two rotary joints (Figure 15c) to provide freedom of rotation in azimuth and two in elevation. The rotary joint insertion loss is no greater than 0.15 dB. The worst case VSWR is 1.35.

The polarizer (Figure 15a) which is mounted in the antenna near the back side of the feed, is a three port device. The antenna port is a 0.328 inch I. D. circular waveguide operating in TE11 mode and connected to the waveguide input of the antenna at the base of the pedestal. The other two ports are in rectangular WR28 waveguide operating in TE_{01} mode and used for connections to the transmitter and the receiver through filters and waveguide switch assembly that make up the system diplexer scheme.

The polarizer consists of a dual-mode transducer and a quarter-wave plate. The two rectangular ports are called in-line port and side port. The side port is used for left-hand circular polarization (LHCP) and the in-line port is used for right-hand circular polarization (RHCP). The electrical characteristics of the polarizer are as follows:

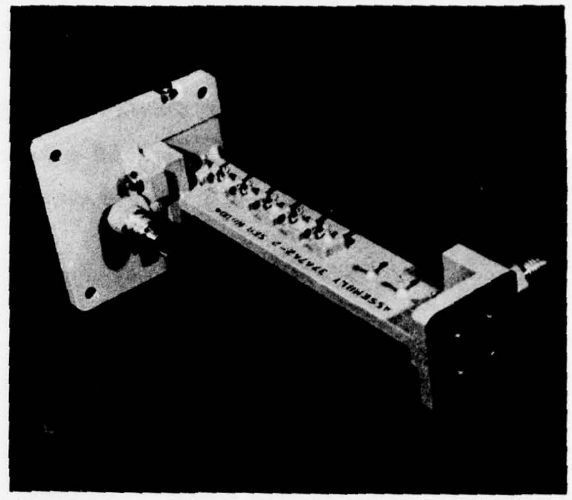
a.	Frequency	35 to 40 GHz
b.	Axial Ratio	
	Side Port (LHCP)	2 dB
	In-Line Port (RHCP)	2.5 dB
c.	VSWR	
	Side Port	$<$ 2.3 dB
	In-Line Port	$<$ 1.42 dB
d.	Isolation	25 dB
e.	Insertion Loss (Estimate)	0.2 dB

The polarizer when terminated in a matched load in circular waveguide has an isolation greater than 25 dB between the two rectangular ports. Each rectangular port of the polarizer is connected to a filter with bandstop and bandpass sections. Although the polarizer provides some isolation between the transmitter and the receiver, practically all of the required amount of isolation, about 120 dB, is provided by the filters in the diplexer system.

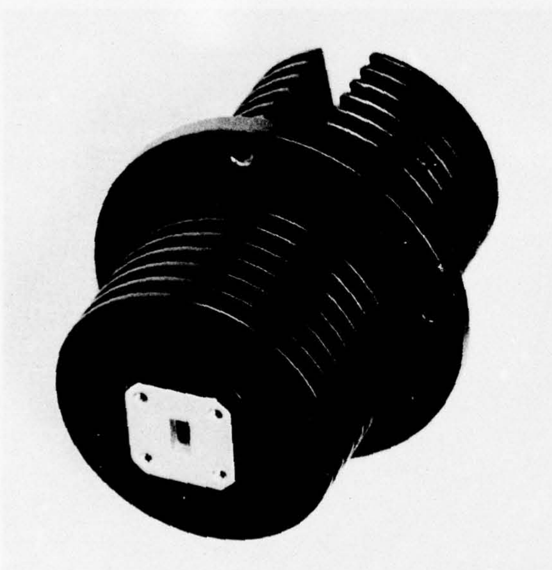
The bandstop section is used to prevent transmitter output from reaching the receiver low noise amplifier. The bandpass section is used to suppress spurious output from the transmitter. It is also used to provide image rejection for the receiver.

The diplexer system is designed to operate at an rf power level of 1 kW. Provision is made for liquid cooling of the polarizer, waveguide, filters, and switches. Figure 16 illustrates the operation of the diplexer system.

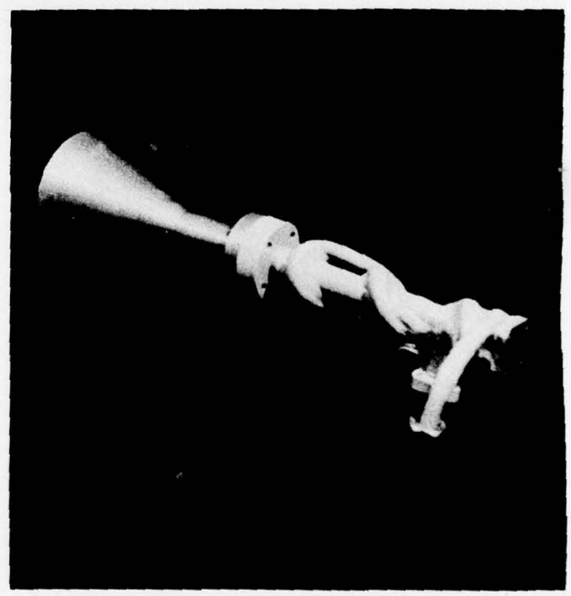
(a) POLARIZER



(b) A_1 L HIGH POWER FILTER



(c) ROTARY JOINT



(d) CIRCULAR FEED AND POLARIZER

Figure 15. Associated Waveguide Run Components

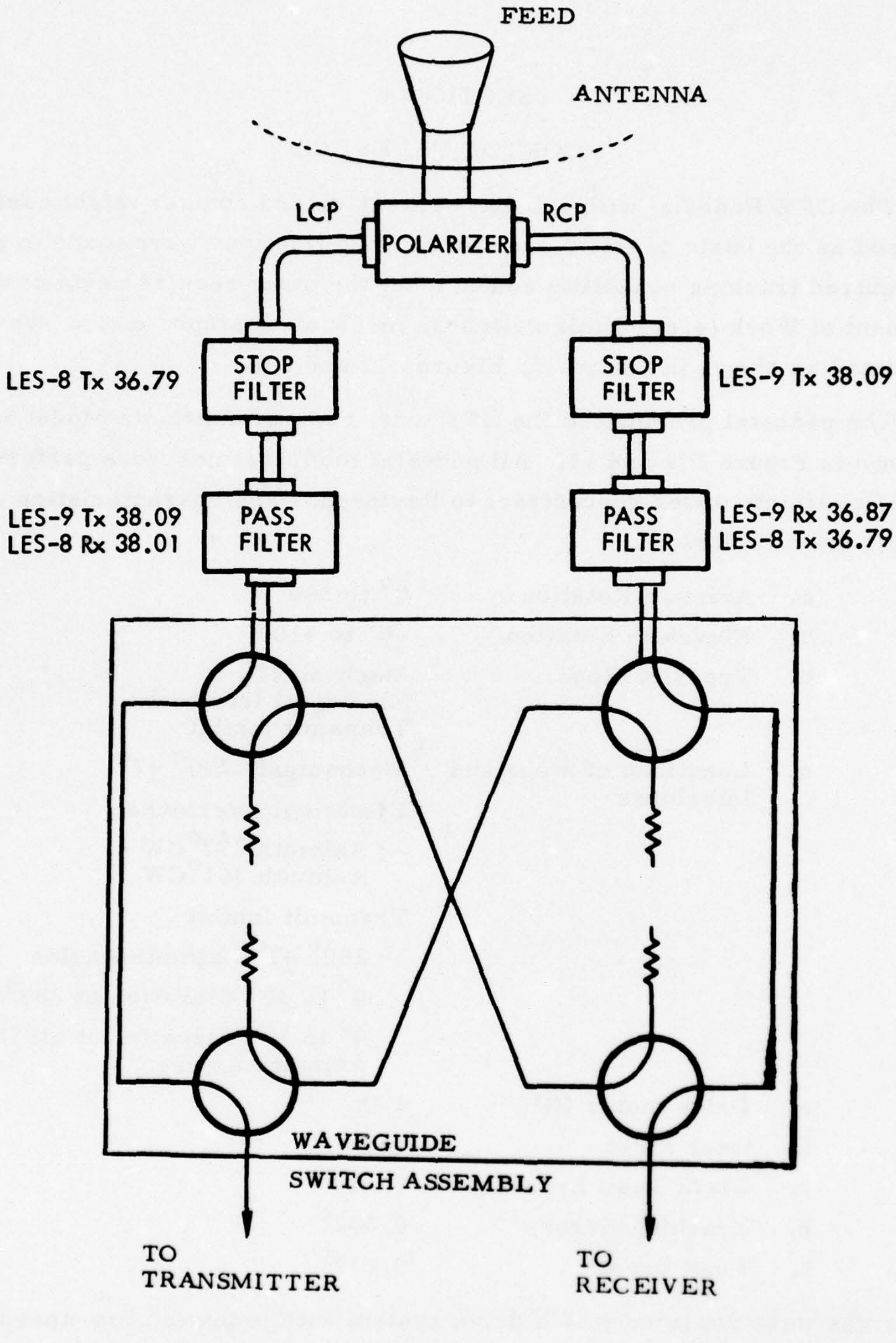


Figure 16. Multiple Switching Network for High Isolation

SECTION 4

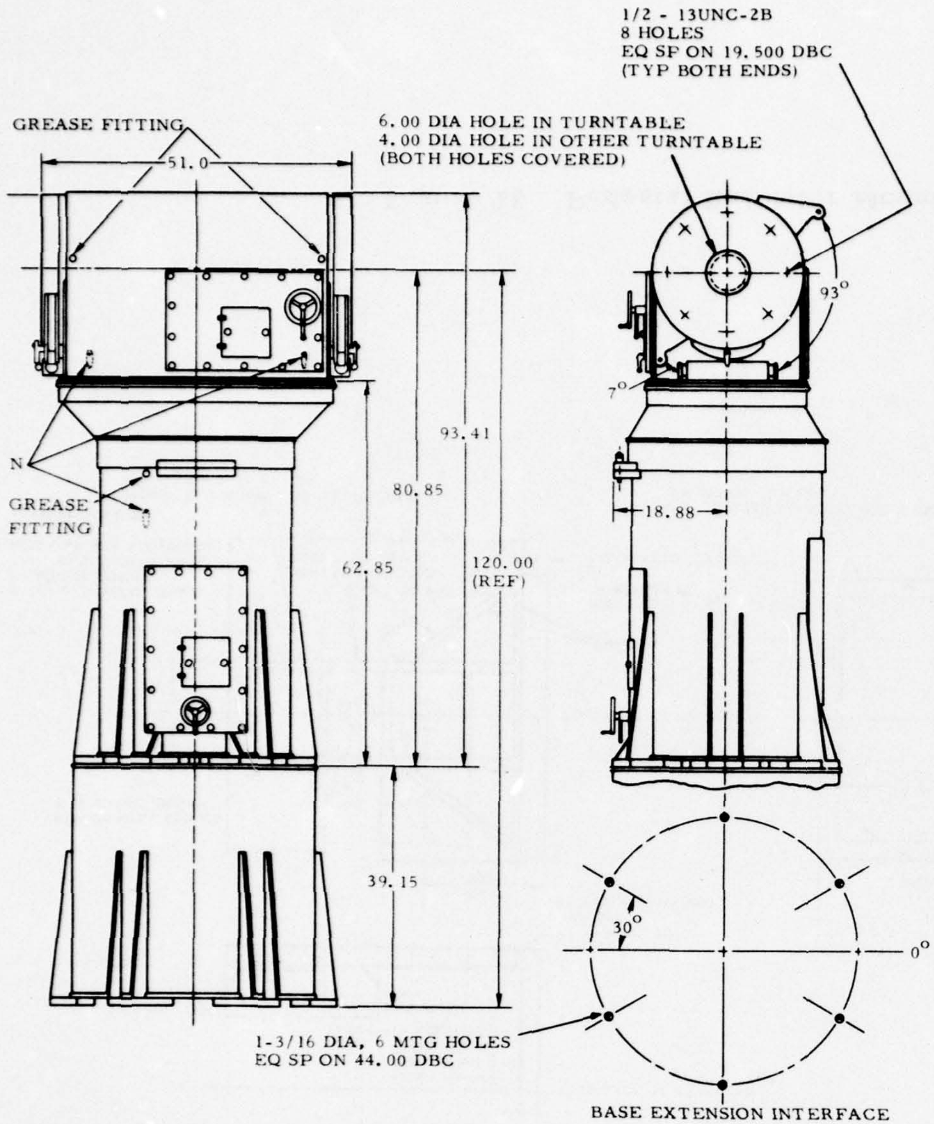
ROOFTOP PEDESTAL

The GFE Pedestal with sub-base extension and counterweight assembly was used as the basic pedestal assembly. Modifications were made to provide the required tracking capability and to meet the other requirements of the Statement of Work (e.g., limit switches, mechanical stops, etc.). Waveguide was routed as shown in Section 3, Figures 13 and 14.

The pedestal provided is the GFE unit, Scientific-Atlanta Model 3205-J94 as shown in Figure 17a and 18. All pedestal modifications were performed by Scientific-Atlanta under subcontract to Raytheon. The characteristics of the pedestal are as follows:

a.	Azimuth Rotation	0° to 360°
b.	Elevation Rotation	-6° to $+100^{\circ}$
c.	Types of Stops	Mechanical Electrical Interlocks Transmit Inhibit
d.	Locations of Stops and Interlocks	Mechanical, $289^{\circ} \pm 7^{\circ}$ Electrical Interlocks Azimuth 277°CW Azimuth 301°CW Transmit Inhibit $289^{\circ} \pm 7^{\circ}$ Azimuth Angles 0° to 30° Elevation at $289^{\circ} \pm 7^{\circ}$ 0° to 10° Elevation at all Other Azimuth Angles
e.	Drive motor HP	1 Hp
f.	Gear Ratio	1400:1
g.	Black Lash Error	0.015°
h.	Tracking Errors	0.002°
i.	Peak Error	0.017°

The drives were replaced with a drive system with improved low-speed capabilities. A system using 1 Hp motors and a 1400:1 gear ratio was incorporated.



(a) PEDESTAL-MECHANICAL LAYOUT

(b) PEDESTAL/ANTENNA CONFIGURATION

Figure 17. Pedestal

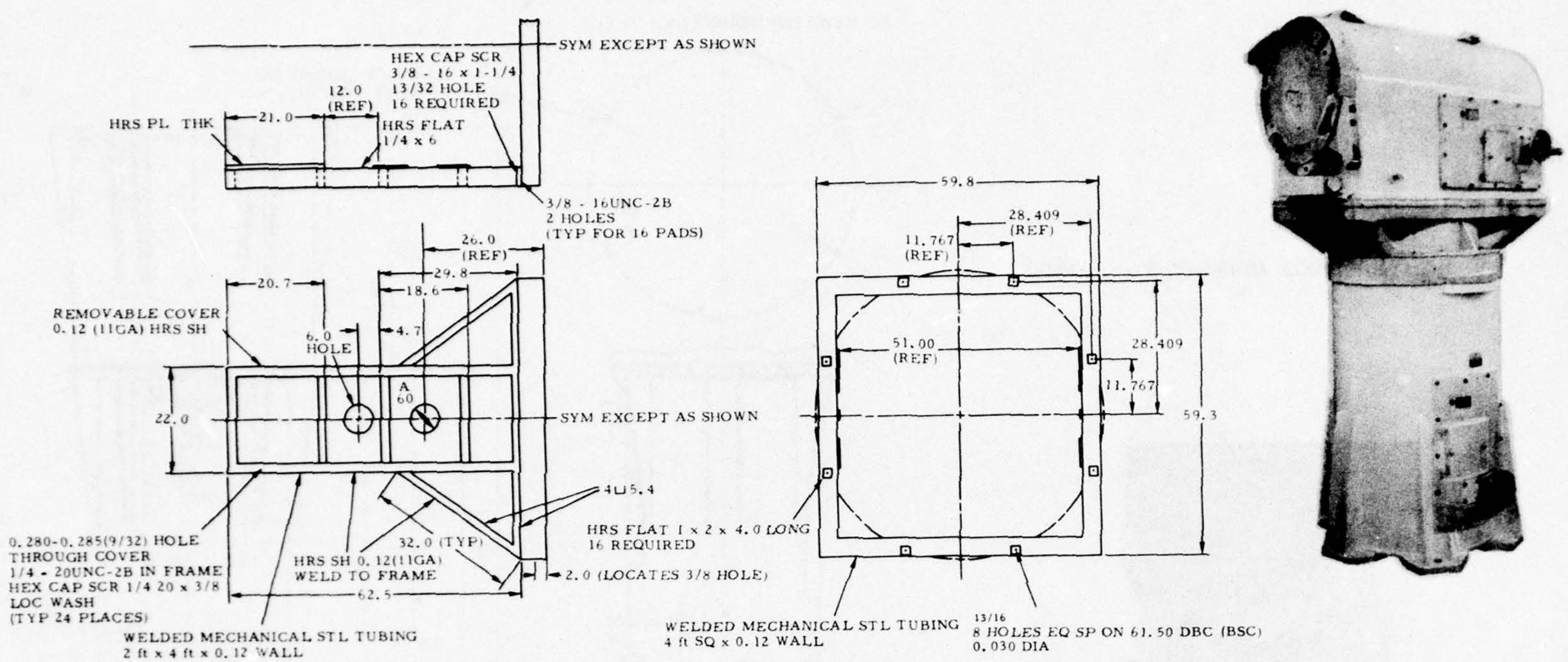


Figure 18. Pedestal Reflector Mount/Counterweight

Closed-loop servo analysis of this configuration resulted in tracking errors of 0.002 degree due to friction perturbations and a backlash of 0.015 degree. Peak errors for this combination will be 0.017 degrees, which is less than the 0.020 degrees required.

A standard Scientific-Atlanta conductor cable wrap assembly is provided on the azimuth axis to transmit power and signals above the azimuth axis. In the elevation axis, less travel occurs and a cable wrap is used for power and signal bends. An independent fail-safe secondary limit switch is provided to protect the cable wrap in the event of primary limit failure.

Mechanical stops, limit switches, and transmit inhibit interlocks are provided on each axis to ensure safe operation and to preclude the presence of any adverse radiation in the prescribed areas. Figures 19, 20 and 21 illustrate the relative details. Mechanical stops are located at 0° elevation and $289^{\circ} \pm 7^{\circ}$ azimuth. The zones at which radiation from the transmitter is inhibited are (1) azimuth cutoff at $289^{\circ} \pm 7^{\circ}$, (2) elevation cutoff at all angles in azimuth from 0° to 10°, and (3) elevation angles of 0° to 30° for azimuth angles $289^{\circ} \pm 7^{\circ}$. When the antenna boresight axis is in the cutoff zone, an electrical control signal will inhibit the operation of the transmitter high-power amplifier. A manual switch is provided to override this interlock feature.

Electromechanical brakes are provided on each axis to hold each axis at the stall torque when the equipment is in standby or off position (including power failures) or in the case when secondary limit is actuated. Stow locks are also provided for each axis. In addition hand cranks are provided on each axis to permit manual positioning of the mount in the event of power failure, servo system problems, or in the case when secondary limits are actuated and the antenna has to be turned out of the limit.

In Figure 1, the locations for the servo power amplifiers for elevation and azimuth is shown in the pedestal. A Model 3633 servo power amplifier is used. The Model 3633 is a solid-state device which provides bidirectional proportional control for dc servo motors up to 1.0 HP. The unit is self-contained and requires an ac power and a bipolar error signal for operation. The characteristics of the SA Model 3633 Power Servo Amplifier are as follows:

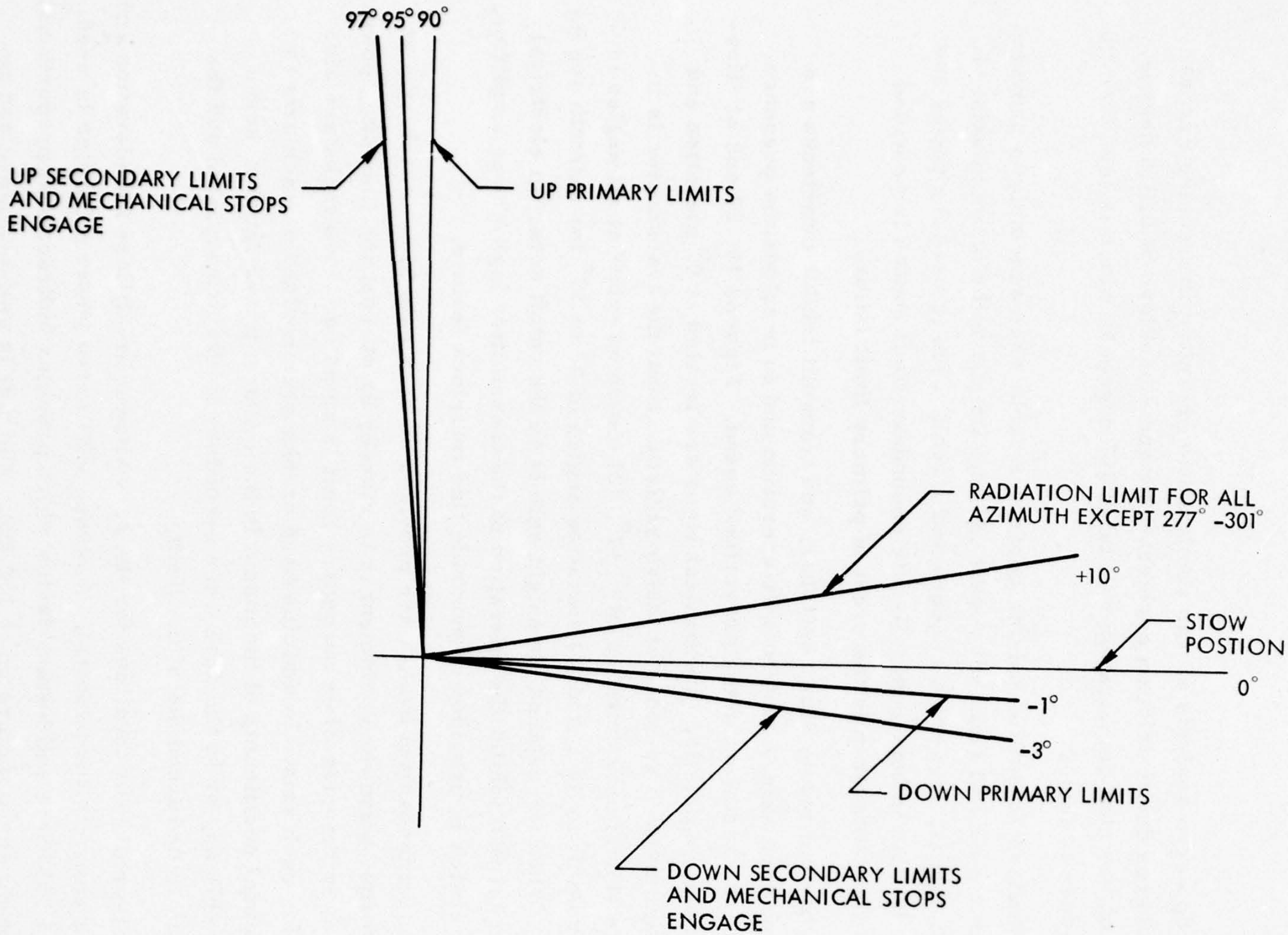


Figure 19. Elevation Stops, Limits and Interlocks

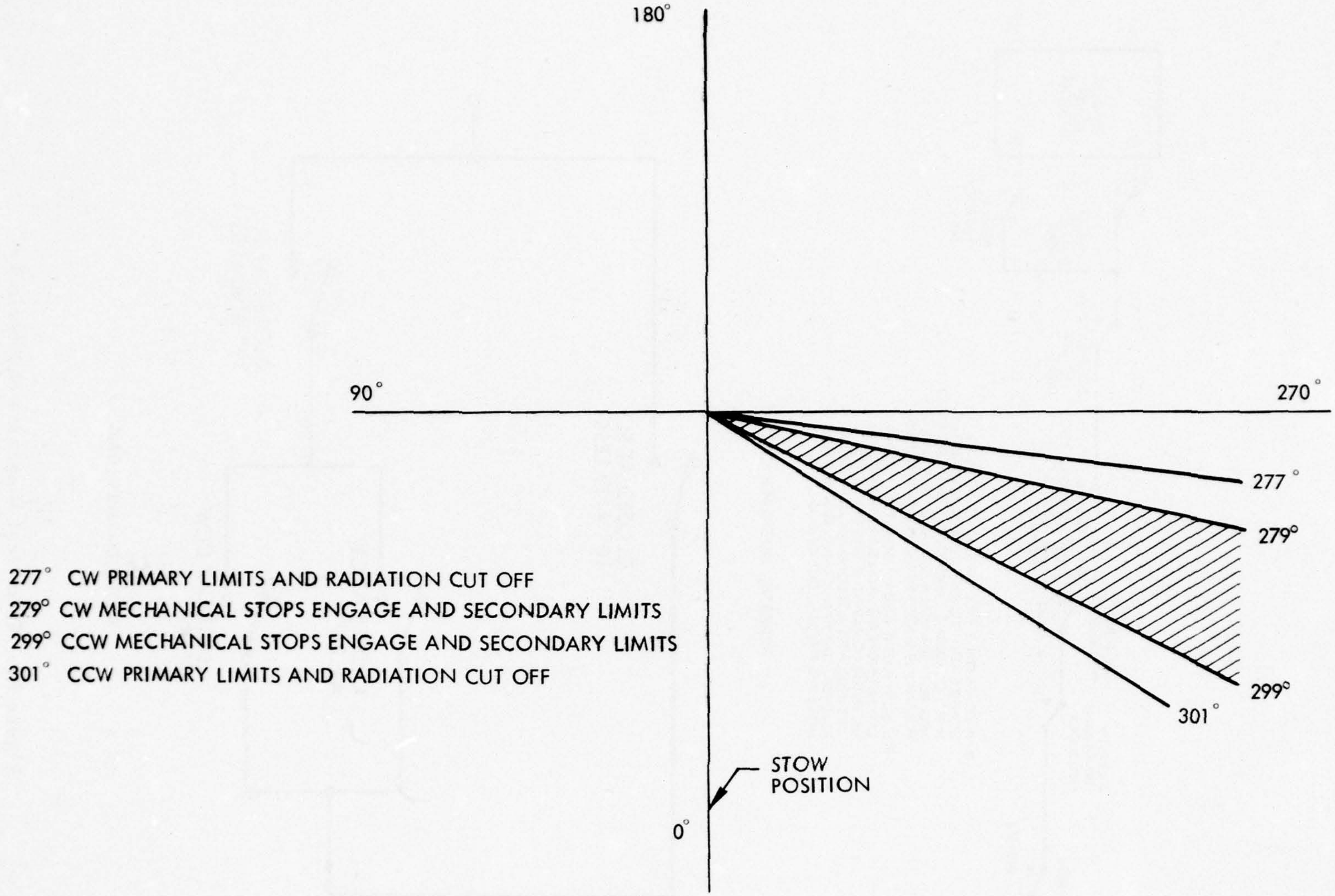
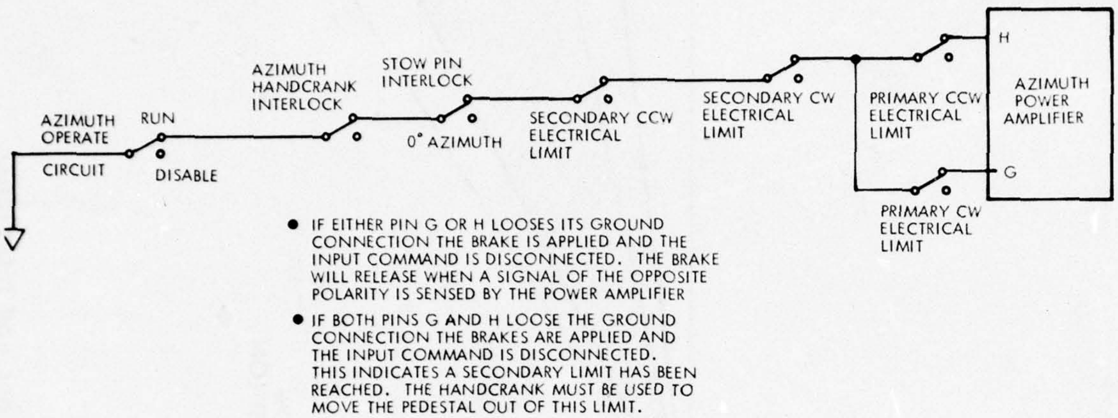
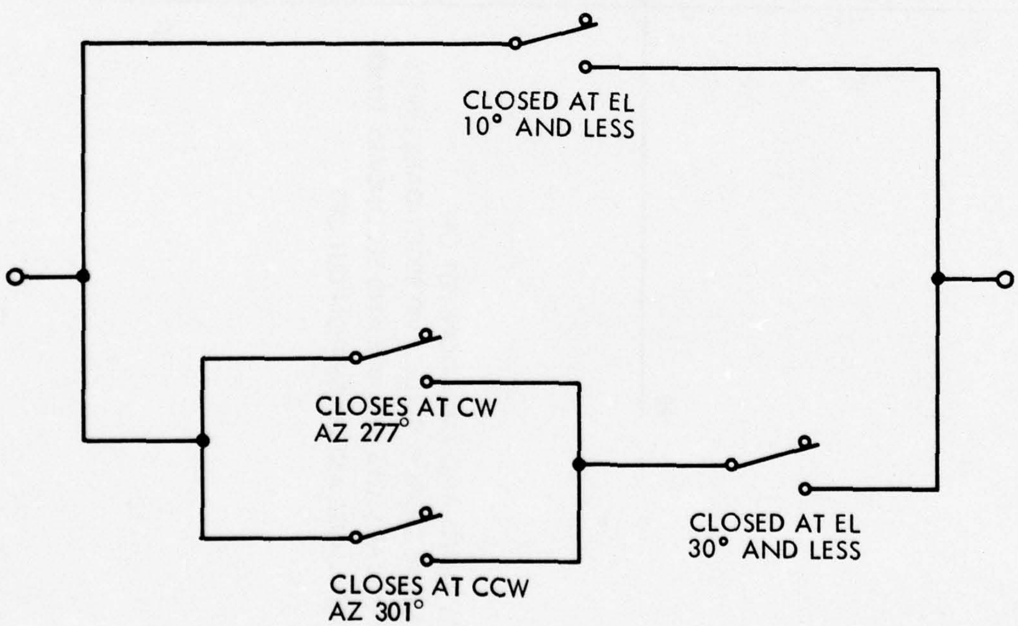


Figure 20. Azimuth Stops, Limits and Interlocks



PEDESTAL INTERLOCK CIRCUIT



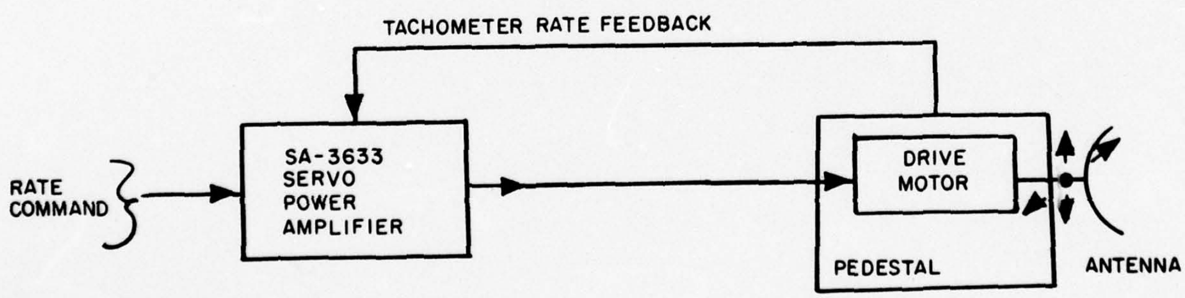
RADIATION LIMIT LOGIC

Figure 21. Electrical Diagrams of Interlocks

a.	Amplifier Type	Solid-State, SCR Bidrectional and Proportional Power Servo Amplifier with optional rate amplifier card to accept tachometer feedback and rate loop compensation
b.	Motor Type at Output	1.0 HP DC Servo
c.	Power Input	120V, 60 Hz, 2 kVA max, 2 phase
d.	Signal Interface	± 10.0 Vdc
e.	Physical Size (Figure 22)	5 x 7 x 18 inches - 40 lbs.

The unit is totally enclosed and all power and control leads are filtered to provide EMI suppression. The unit performs as an element of a closed-loop servo system (Figure 22). The power amplifier acts as a speed controller for the drive motor, and the motor speed is proportional to the dc rate-command input. Speed regulation is achieved by negative feedback from a dc tachometer. This feedback is a linear representation of the actual motor speed so that when it is compared with the dc rate command the result is a rate-error signal that approaches zero. Good control over speed and regulation is achieved.

(a) PHYSICAL CONFIGURATION



(b) BASIC SERVO LOOP CONFIGURATION

Figure 22. Model SA-3633, Servo Power Amplifier Unit

SECTION 5

SECANT CORRECTION UNIT

Referring to Figure 2, the Secant Correction Unit (SA-3770) is located in the azimuth drive chain with an elevation feedback. The unit itself is located in the control cabinet in the rooftop shelter.

The 3770 Secant Correction Unit provides an error signal gain correction to the azimuth servo system to compensate for azimuth auto tracking sensitivity reduction as a function of increasing elevation angles. The effect arises from the coordinate transformation necessary to relate the x-y coordinate system in which the auto tracking error signals are derived to the elevation-over-azimuth coordinate system in which the servo system operates. At low elevation angles, one space degree is about equal to one pedestal azimuth degree. At high elevation angles, one space degree is equivalent to many degrees of pedestal azimuth angle. To optimize autotrack performance, the secant amplifier is installed in the azimuth servo channel. When gain is controlled by a synchro-TR-drive cosine potentiometer which is coupled to an elevation axis synchro TX, it provides unity gain at zero degrees elevation angle and a gain of about 10 to 85 degrees elevation angle. Therefore, the cosine potentiometer variation changes the gain as the secant of the elevation angle. The control modifies the shape of the gain curve from a true secant shape where the azimuth channel gain equals infinity at the elevation angle of 90 degrees to a curve which gives a gain of about 10 to 85 degrees. Figure 23 illustrates the basic concepts associated with the Secant Correction Unit.

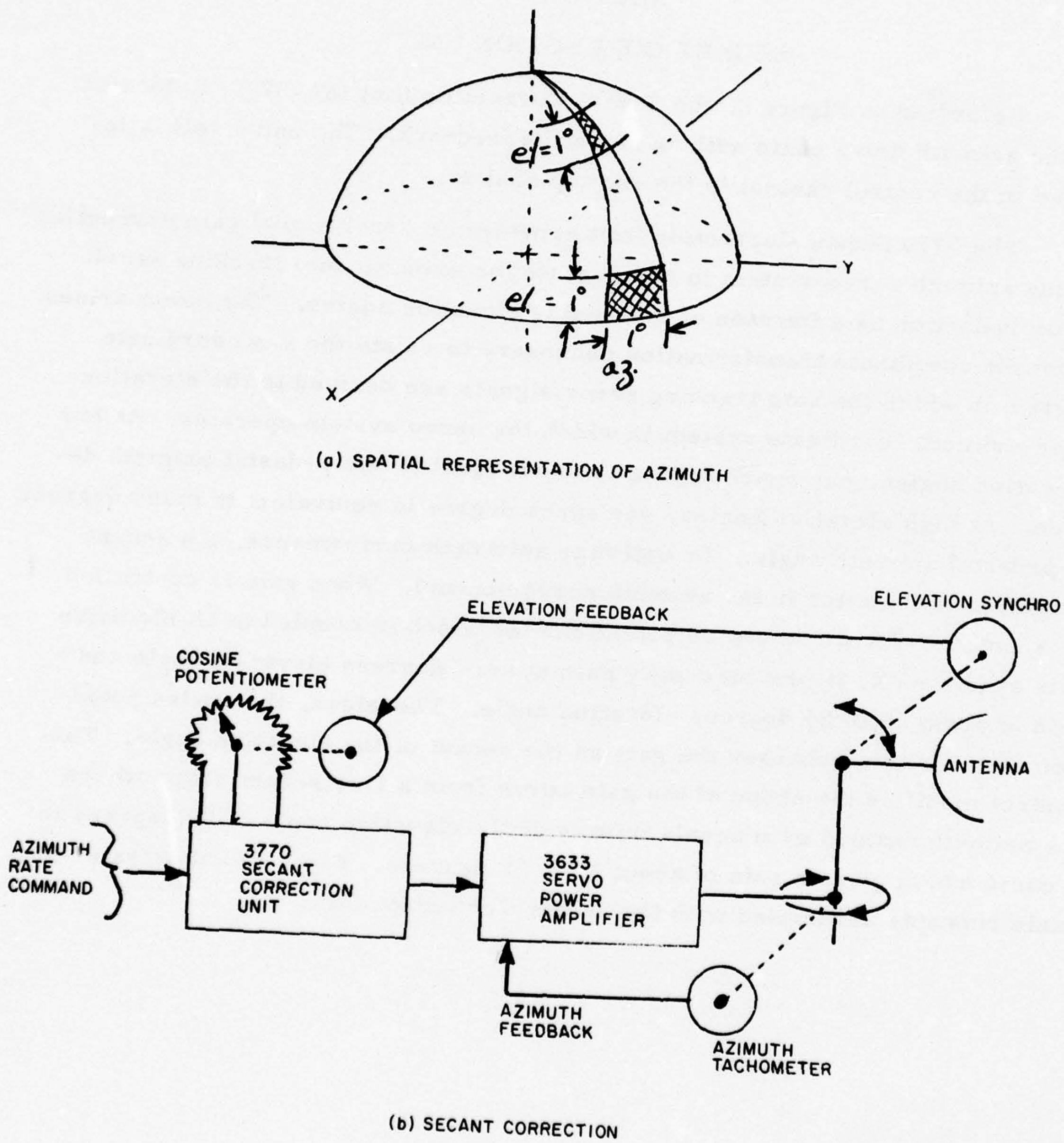


Figure 23. Basic Configuration of Secant Gain Correction

SECTION 6

JOY STICK

Referring to Figure 24, the Joystick provides one-hand velocity control of the antenna in both axis (elevation and azimuth). A "dead-man" switch atop the joystick selects the Joystick mode (manual) when actuated transferring control of the pedestal (except during standby) from the Antenna Position Control Unit to the joystick. The velocity commanded by the Joystick is directly proportional to the angular movement (fore and aft for elevation, right and left for azimuth) of the Joystick from the center position. The Joystick is spring-loaded to the center position. Potentiometers for both azimuth and elevation in the joystick control unit is excited with ± 15 Vdc. The center tap of the potentiometer is grounded. As the handle is moved to one side, the potentiometer wiper moves off ground. This voltage is used as a rate-command signal by a servo system to operate the pedestal drive. The joystick is mounted in the control located in the Rooftop shelter.

The joystick will be utilized in Active mode where the Antenna can be slewed to the proper spatial position for elevation and azimuth angle. At this point, operation by the joystick is discontinued and auto search by the antenna position Control Unit is actuated. Figure 2 shows the relationship of the joystick to the system.

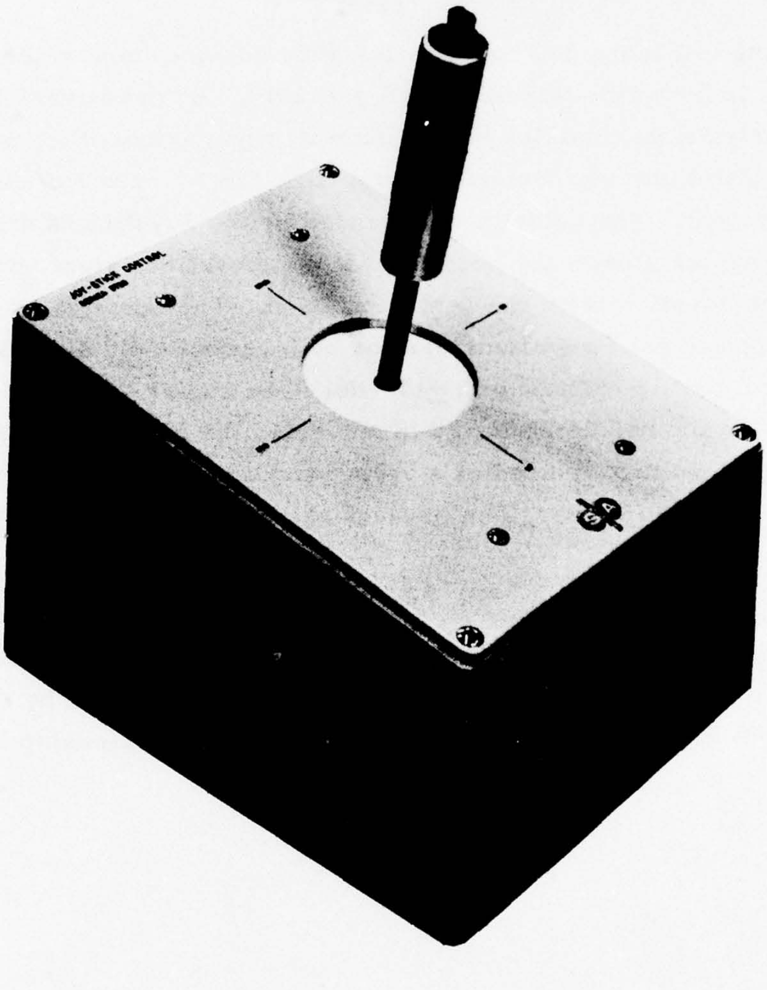


Figure 24. Model 3721A Joystick Control Unit

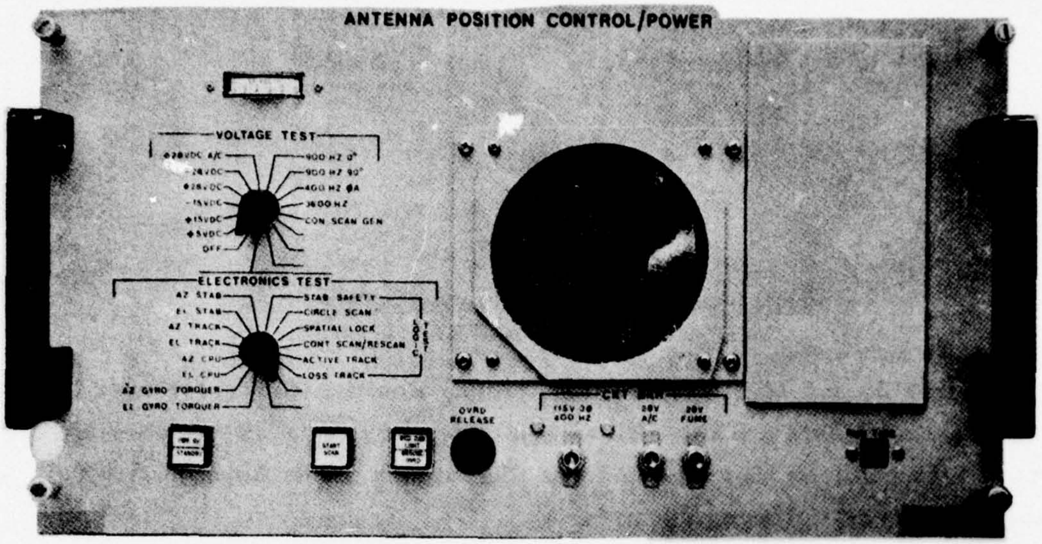
SECTION 7

ANTENNA POSITION CONTROL/POWER UNIT AND ANTENNA CONTROL PANEL

Figures 25 and 26 illustrate the Antenna Position Control/Power Unit and the Antenna Control Unit. These two units provide the Elevation and Azimuth rate command signals to drive the antenna. The Antenna Control capabilities are as follows:

1.	Designation (Pointing)	a.	Manual or
		b.	Computer to any desired Azimuth and elevation coordinates
2.	Acquisition	a.	Circle scan Pattern about a designated point
		b.	Four square degree Pattern
		c.	Each point in pattern scanned by three Traverses of main beam
		d.	Automatic acquisition using threshold and frequency locking circuits in auto-track receiver
3.	Tracking	a.	Active tracking using demodulated receiver error signals for azimuth and elevation servo commands
		b.	Passive tracking using computer commands
4.	Search Pattern		Concentric Circles, 25 square degrees
5.	Search Time		108 seconds for full pattern
6.	Type of Tracking		Conical scan at 64.3 Hz
7.	Tracking accuracy		$\pm 0.02^{\circ}$
8.	Tracking bandwidth		0.1 Hz

The antenna system can be placed in the active mode of operation by pressing Manual Desig mode on the Antenna Control Panel. The operator can manipulate the slew controls to point the antenna to predetermined elevation and



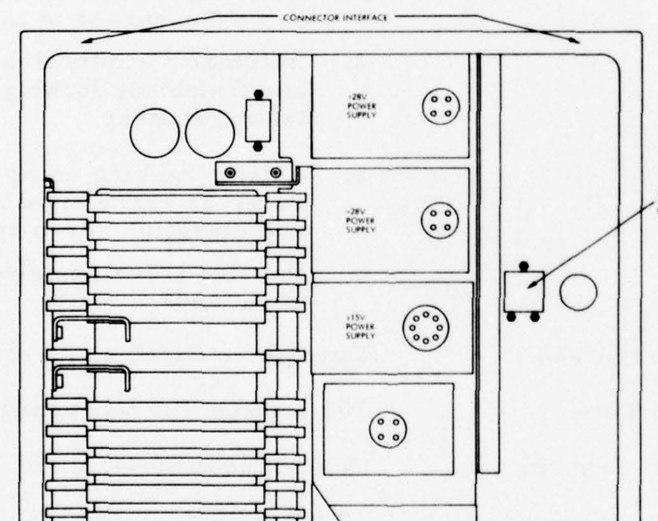


Figure 25. Antenna Position Control/Power Unit

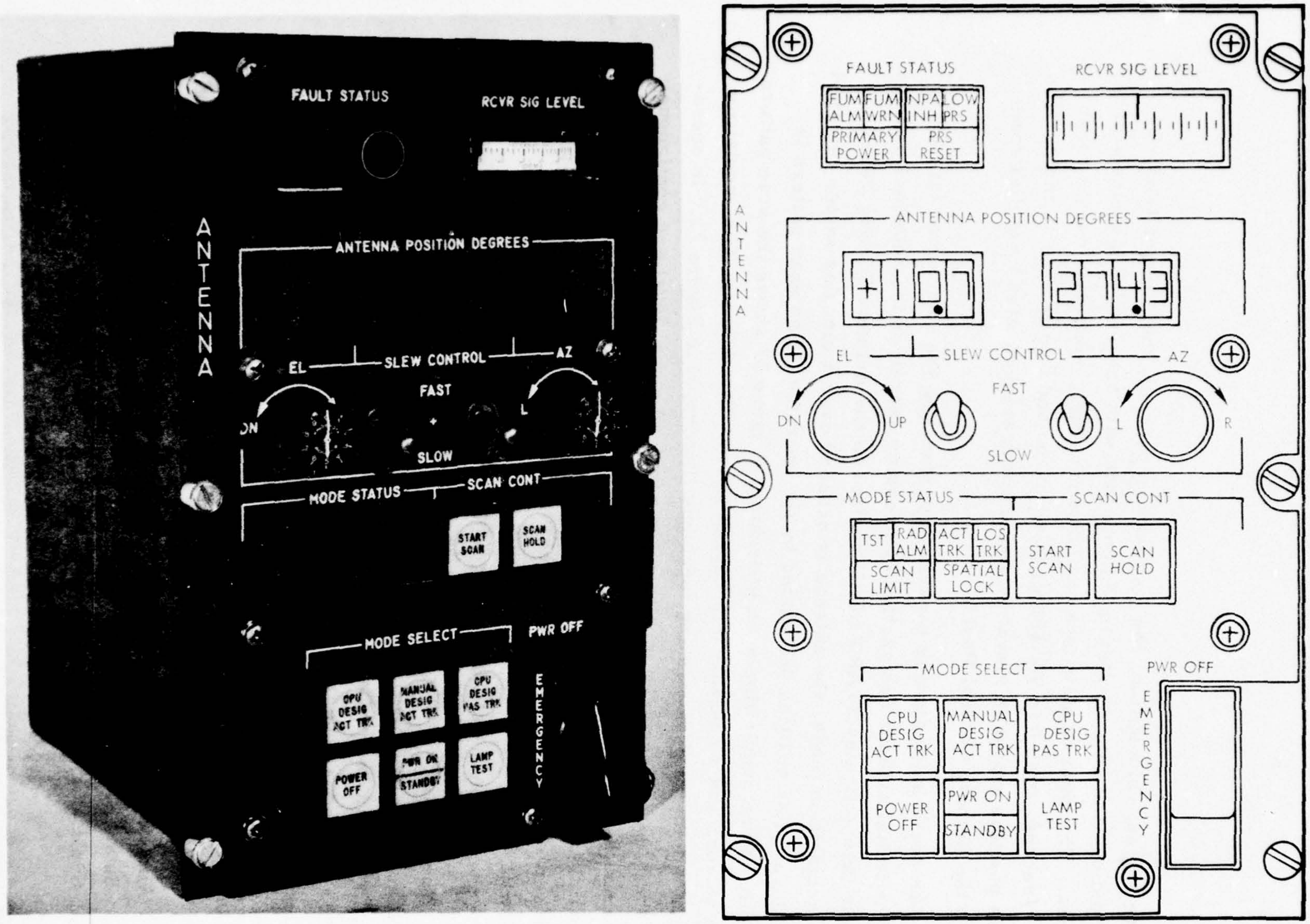


Figure 26. Antenna Control Panel

azimuth angles. In addition, the joystick can override the Antenna Control Panel and provide antenna slewing in both axis with one-handed movement of the stick. The antenna slew rate can be continuously controlled over a range of $\pm 10^{\circ}$/second, over 0 to 90° travel in elevation and 0 to 360° in azimuth. The antenna position angles in elevation and azimuth are indicated by digital readouts on the Remote Control Panel.

The servo subsystem is capable of performing the acquisition function after the initial antenna designation by pressing search on the autotrack receive which in turn activates START SCAN control on the Antenna Control Panel. In the acquisition mode, the antenna is scanned over a circular sector centered about the angular position designated by the operator. The scan pattern is controlled by an acquisition scan generator. Figure 27 shows the scan pattern of the antenna and a possible intercept of the satellite signal. The acquisition function employs a peak-seeking technique illustrated in Figure 21. In operation, the Ka-Band receiver monitors the received signal level and continuously compares the level with a preset threshold. When the threshold is exceeded, a "spatial lock-on" signal is generated in the autotrack receiver and passed on to the servo subsystem as a command to stop scanning. At this point the autotrack will frequency and phase lock and continue passing pointing error information to the Antenna Position Control Unit.

The acquisition scan pattern is determined by the frequency of a timing signal and is varied by means of an RC network in the Servo Control Interface Unit. The scan sector can cover an area as large as 25 square degrees or as small as 2.5 square degrees. The scan pattern is a series of 13 concentric circles. The circles can be spaced so that each point in a search sector is scanned by at least three traverses of the main beam within the half-power point. For the 10 foot rooftop antenna, the beamwidth of about 0.2° will result in a scan sector of about 2.8°.

An active track capability is provided by spinning the antenna subreflector at a constant frequency to conical scan the main beam. This results in an amplitude modulated rf which is down converted and envelope detected in the receiver.

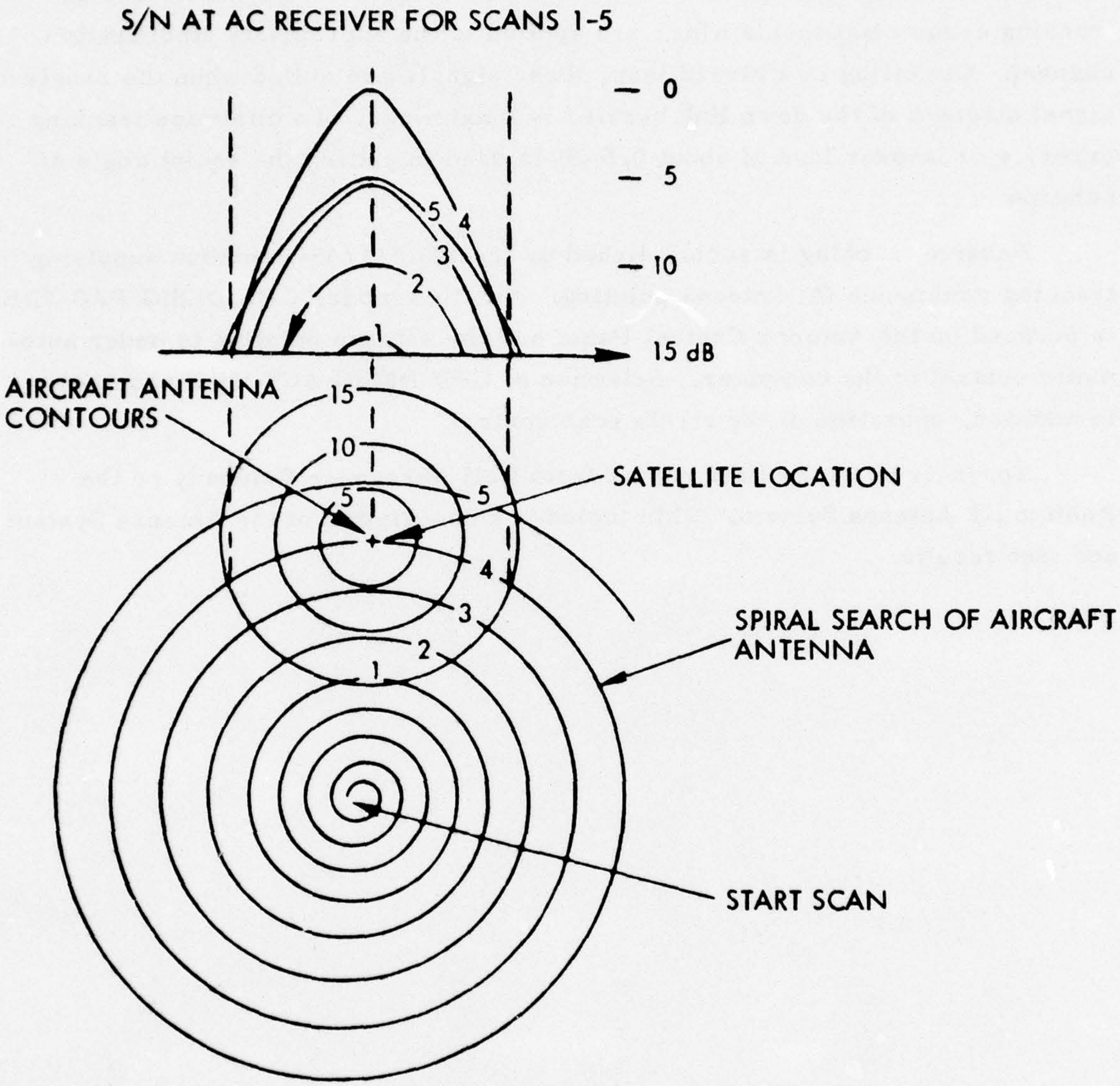


Figure 27. Search Scan Pattern and Peak-seeking Technique

This signal at the conical scan frequency is further processed by a phase sensitive demodulator in the Antenna Control Group to derive the Az and El tracking error components which are applied to the appropriate stabilization channel. Operating in a closed loop, these signals are nulled when the received signal strength of the down link carrier is maximized. To minimize tracking error, a crossover loss of about 0.5 dB is used in setting the squint angle of nutation.

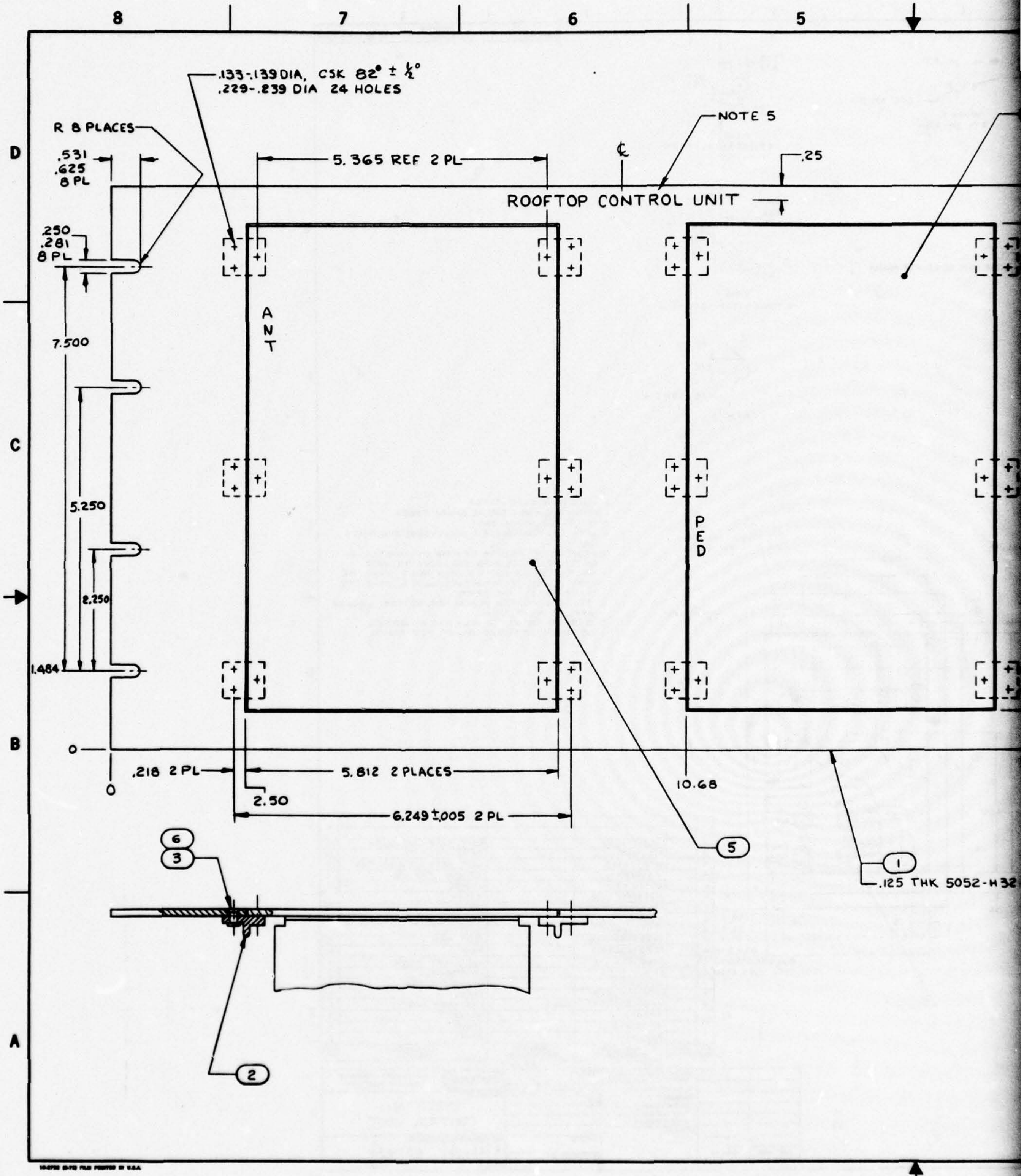
Passive tracking is accomplished by the PDP 11/45 computer supplying tracking commands for antenna pointing. For this mode, CPU DESIG PAS TRK is pressed on the Antenna Control Panel and the antenna pointing is under automatic control of the computer. Selection of CPU DESIG ACT TRK requires, in addition, operation of the circle scan control.

Appendix IV is the final report from Bell Aerospace Company on the Rooftop Ka Antenna System. This includes a description of the Antenna System and test results.

SECTION 8

ROOFTOP CONTROL UNIT

The Rooftop Control Unit (Figure 28) contains the antenna control unit for the 3 foot diameter antenna shown in Figure 26. Housed alongside the antenna control unit is the pedestal control unit for the 10 foot diameter antenna (Figure 29) for power to the SA pedestal (Figure 22), secant correction unit and joystick. This unit also has an emergency power off switch.



8
7
6
5
D
C
B
A
.133-.139 DIA, CSK 82° ± ½°
.229-.239 DIA 24 HOLES
R 8 PLACES
.531
.625
8 PL
5.365 REF 2 PL
NOTE 5
.25
ROOFTOP CONTROL UNIT
.250
.281
8 PL
ANT
7.500
5.250
2.250
1.484
PED
0
0
.218 2 PL
5.812 2 PLACES
2.50
10.68
6.249 ±.005 2 PL
5
1
.125 THK 5052-H32
6
3
2

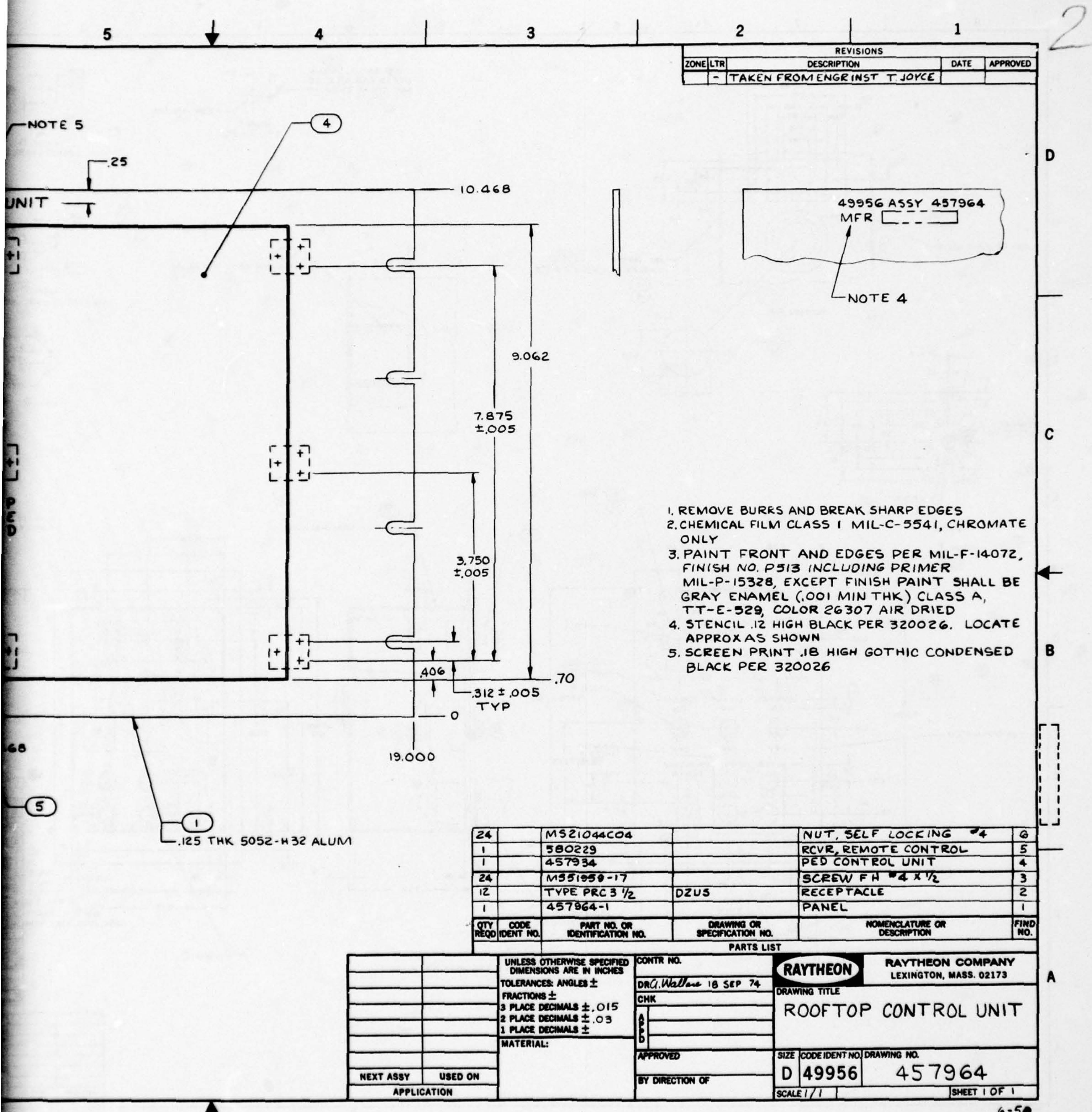
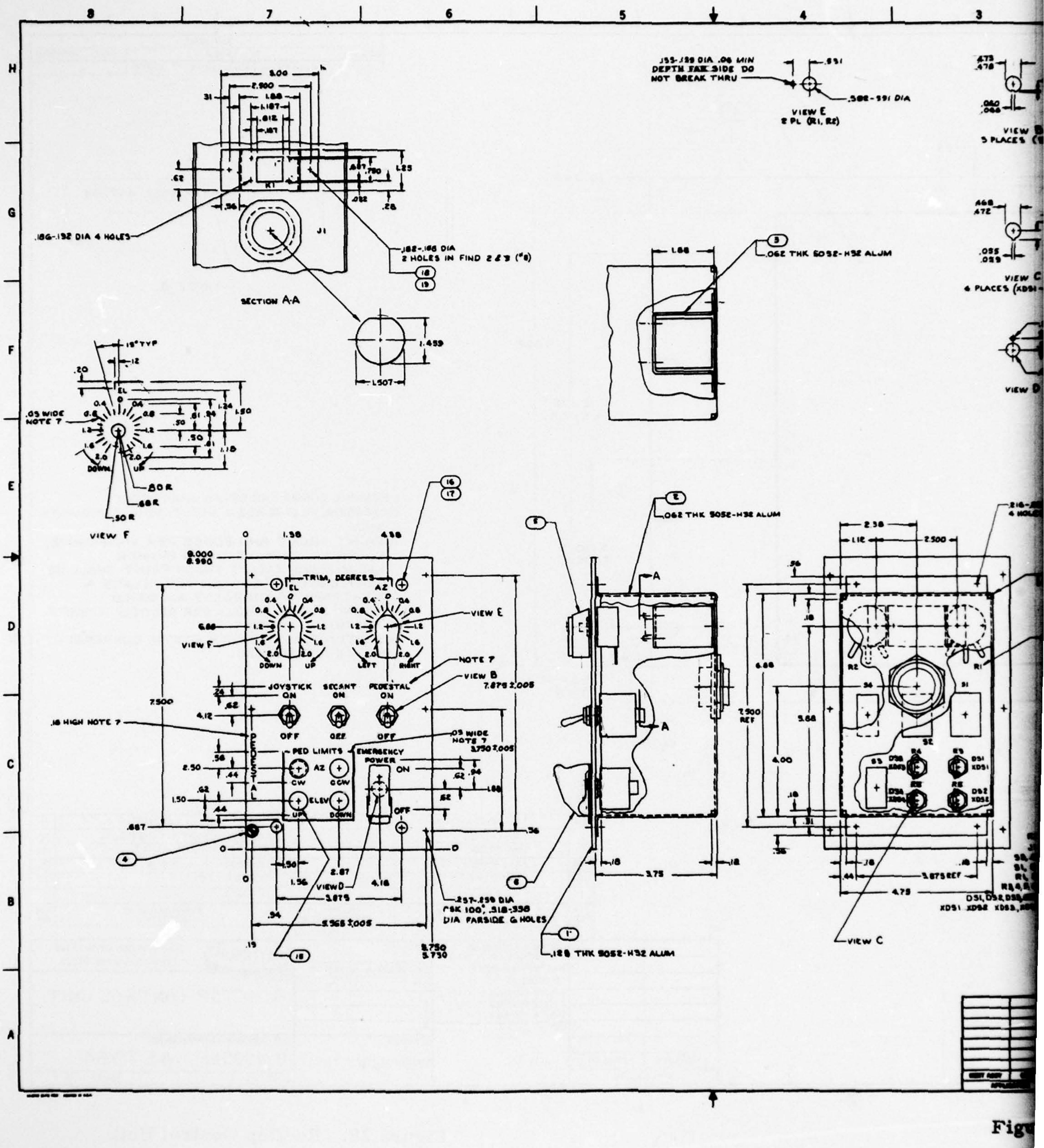


Figure 28. Rooftop Control Unit



SECTION A-A
VIEW F
VIEW E
2 PL (R1, R2)
.062 THK 5052-H32 ALUM
.128 THK 5052-H32 ALUM
TRIM, DEGREES
EL
AZ
DOWN
UP
LEFT
RIGHT
JOYSTICK
SECANT
PEDESTAL
ON
OFF
PED LIMITS
EMERGENCY POWER
CW
CCW
ELEV
NOTE 7
.18 HIGH NOTE 7
.03 WIDE NOTE 7
VIEW B
VIEW C
VIEW D
3 PLACES
4 PLACES
.186-.192 DIA 4 HOLES
.182-.166 DIA 2 HOLES IN FIND 2 & 3 (#8)
NOT BREAK THRU
.257-.259 DIA CSK 100°, .318-.338 DIA FARSIDE 6 HOLES
.50 R
.68 R
.80 R
15° TYP

Figu

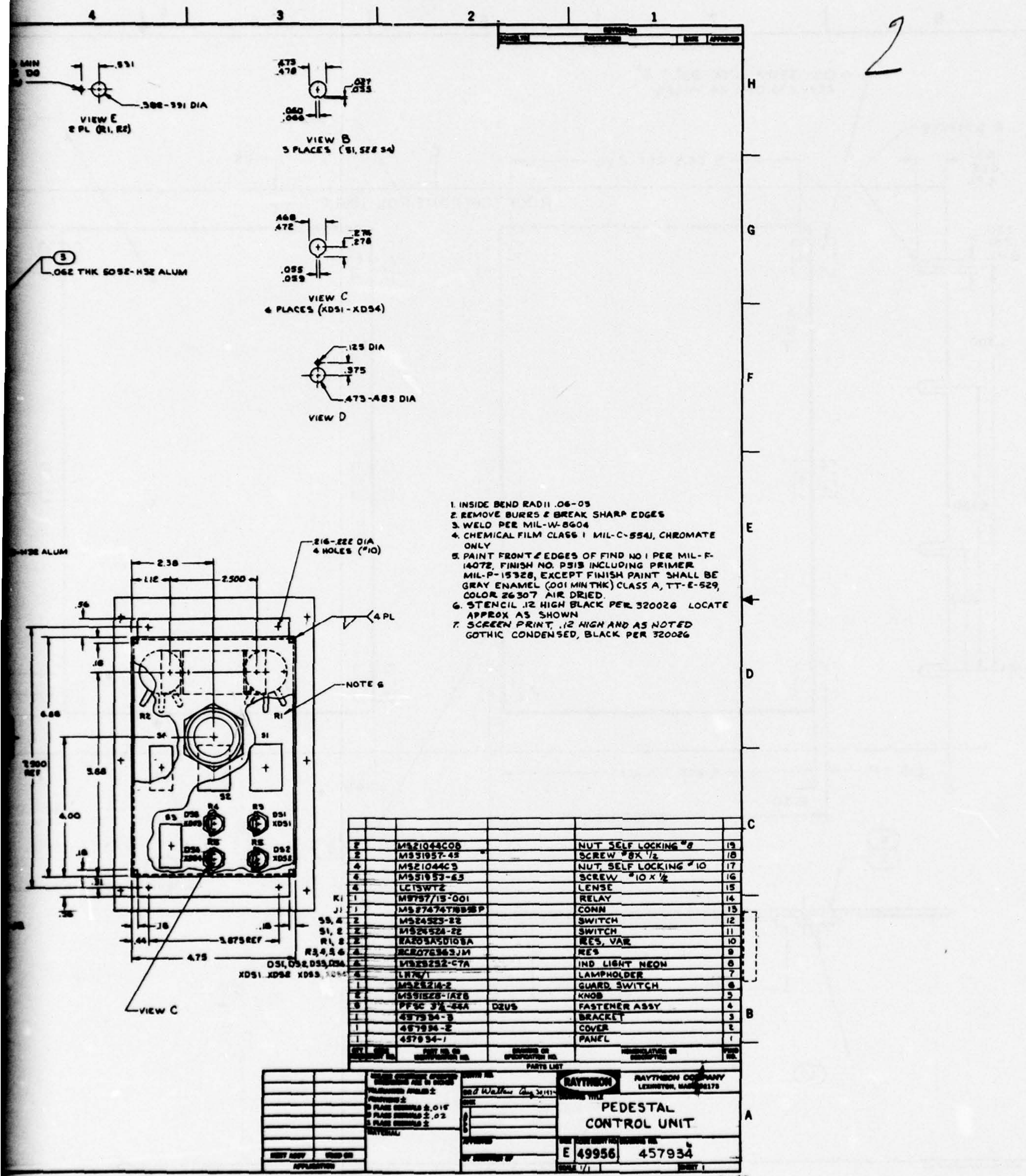


Figure 29. Pedestal Control Unit

SECTION 9

ANTENNA CONTROL INTERFACE UNIT

The computer inputs to the Antenna Control Interface Unit antenna position errors in azimuth and elevation. Figure 2 illustrates the relationship of the antenna control intervace with the Antenna Position Control/Power Unit. Figure 30 is a block diagram of the computer interface. The Computer Interface Unit consist of Synchro/Digital converters and Digital/Analog Converter, with the following characteristics:

1. Synchro/Digital Converter
   a. 16 bit resolution
   b. LSB = 0.005^{o}
   c. TTL compatible
2. Digital/Analog Converter
   a. 12 bit resolution
   b. Scale factor = 125 mV/deg
   c. Full scale of $\pm 8V$ or $\pm 64^{o}$
   d. TTL compatible
   e. Strobe 50 ns minimum

Inputs in Digital form, from the PDP 11/45 computer, are applied through DR11-C register interface to separate azimuth and elevation digital-to-analog converters. The DR11-C provides the logic and buffer register necessary for transfers of 16-bit input and output data between the PDP-11/45 System and the Computer Interface Unit. The converters are the DAC-12-QM model. The converter analog outputs have a sensitivity of 125 millivolts/degree, which is compatible with the interface requirement in the Ka-Band Rooftop terminal.

Likewise, DDC 4684 Synchro/digital converters convert the azimuth and elevation synchro position indications to digital form and the output is routed through the DR11-C register interface to the PDP-11/45 computer. The converter digital output least sufficient bit (LSB) represents 0.005^{o}. Figure 31 represents the timing sequence of the synchro/digital converter.

The Antenna Control Interface Unit (Figure 32) is physically located in the CSEL facility. The analog inputs and outputs are carried with appropriate cables between the CSEL and Rooftop shelter.

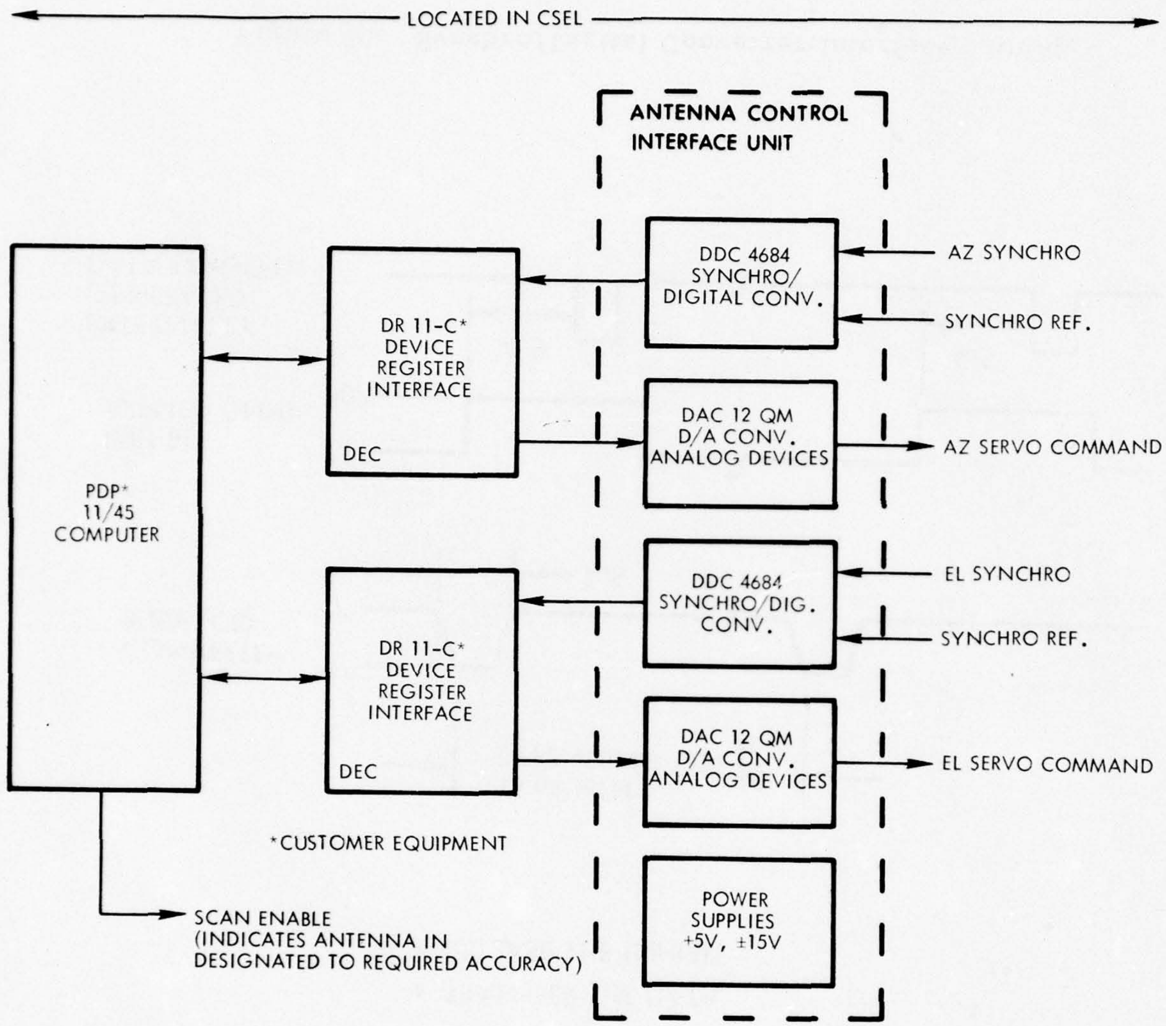


Figure 30. Computer Interface Block Diagram

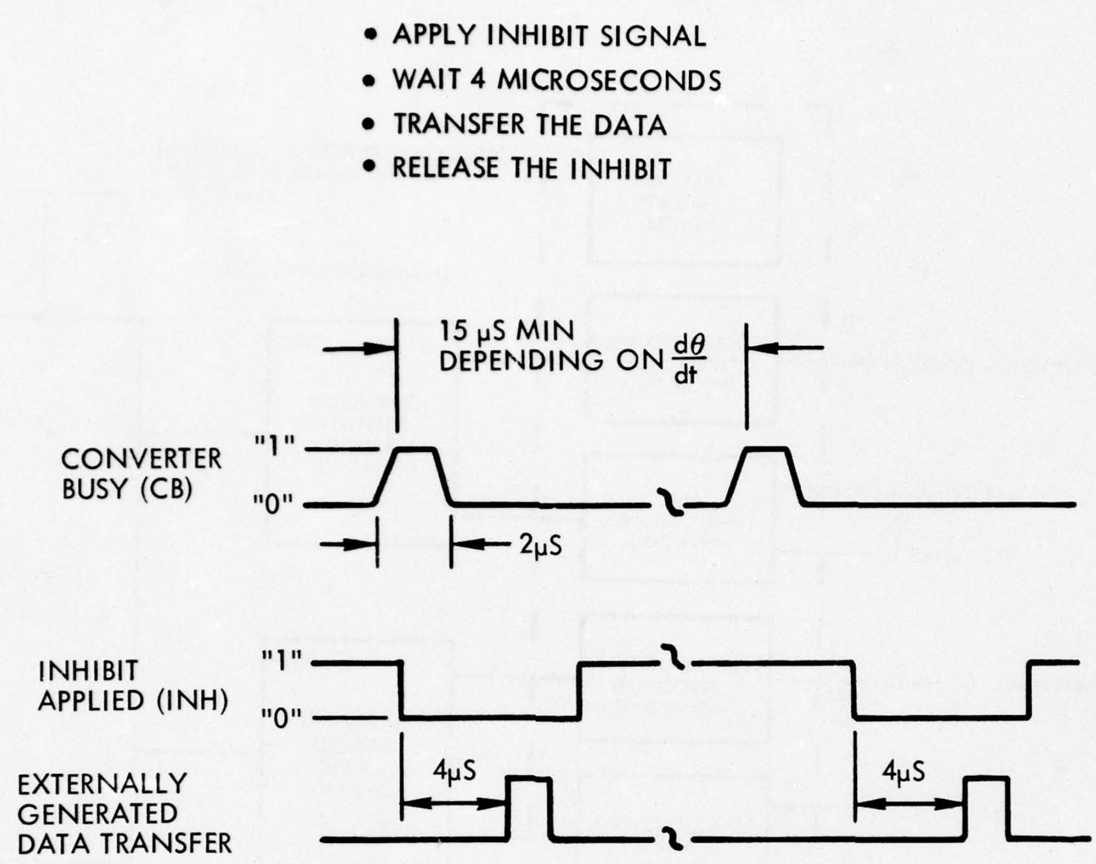


Figure 31. Synchro/Digital Converter Interface Timing

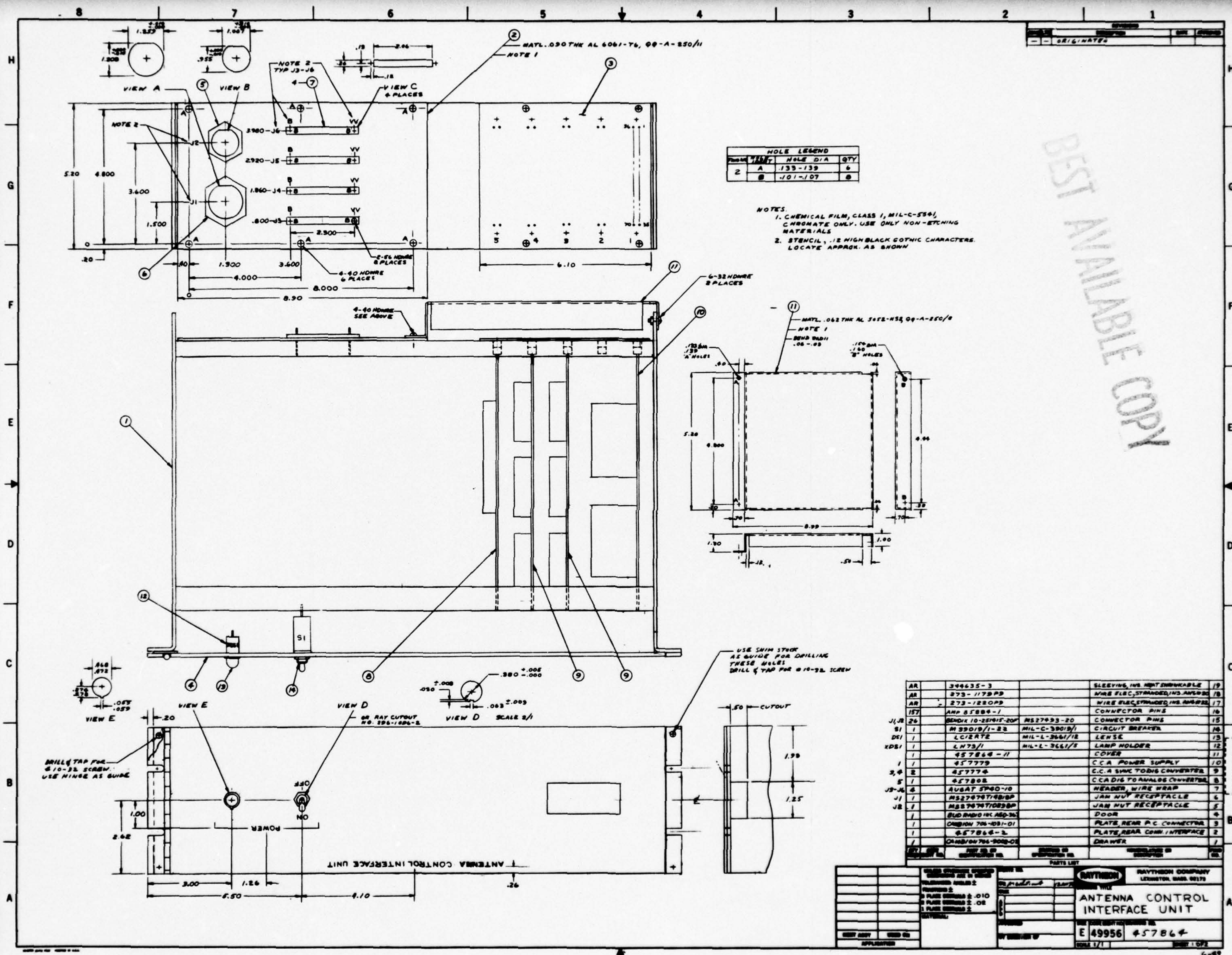


Figure 32. Antenna Control Interface Unit

SECTION 10

RADOME/PRESSURIZATION SYSTEM

The Rooftop Antenna System is equipped with an air-inflatable radome. Figure 4 illustrates the radome fully inflated and deflated during installation of antenna and pedestal. The radome is thin-walled and very thin with respect to the wavelength. The transmission loss increases with the relative dielectric constant of the material, the thickness, the obliqueness of the incidence angle, and the polarization of the incident wave.

The diameter of the radome is 22 feet, whereas the antenna diameter is 10 feet. Therefore, the incidence angle will be nearly normal, being less than 25° even for rays emanating from the edge of the antenna.

The radome characteristics are as follows:

a.	Size	22 feet diameter (Figure 33)
b.	Shape	Prolate
c.	Construction	Single-ply conventional vertical gore shaped panels
d.	Clearance	24 inches (minimum)
e.	Operating Winds	40 mph
f.	Survival Winds	100 mph
g.	Anchorage	Base ring/segmented Clamping ring (Figure 34)
h.	Material	Vinyl-coated nylon with urethane top coating
i.	Thickness	.025 inches
j.	Attenuation, dB 35 GHz to 40 GHz	
k.	Tensile Strength	300 psi

RADOME MATERIAL

In-house test were performed on various Radome materials to verify rf characteristics of each material. These tests were performed on four different material samples supplied by two different vendors (see Figure 35 for identification and description of materials tested). Measurements were made by

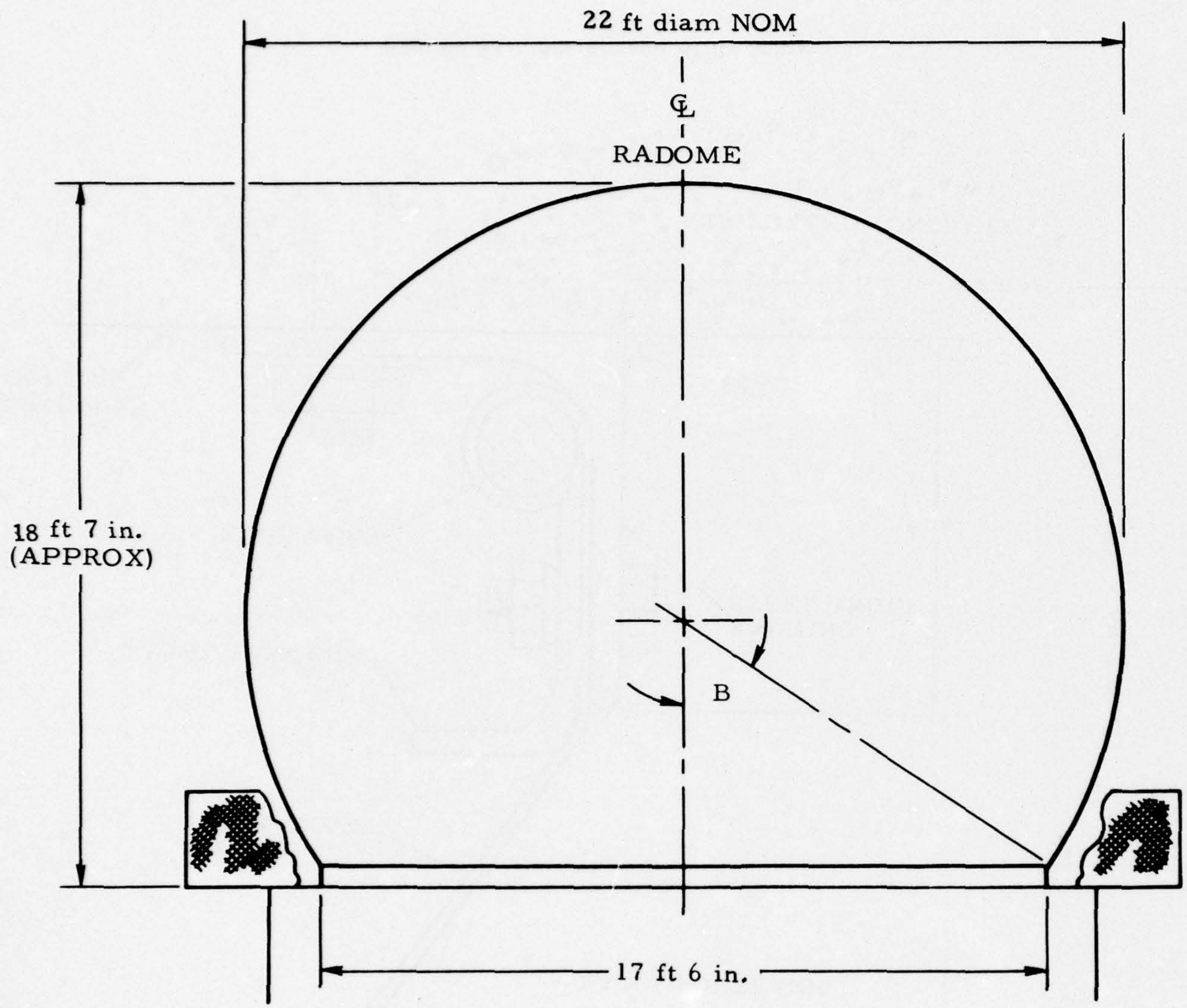


Figure 33. Radome Size and Geometry

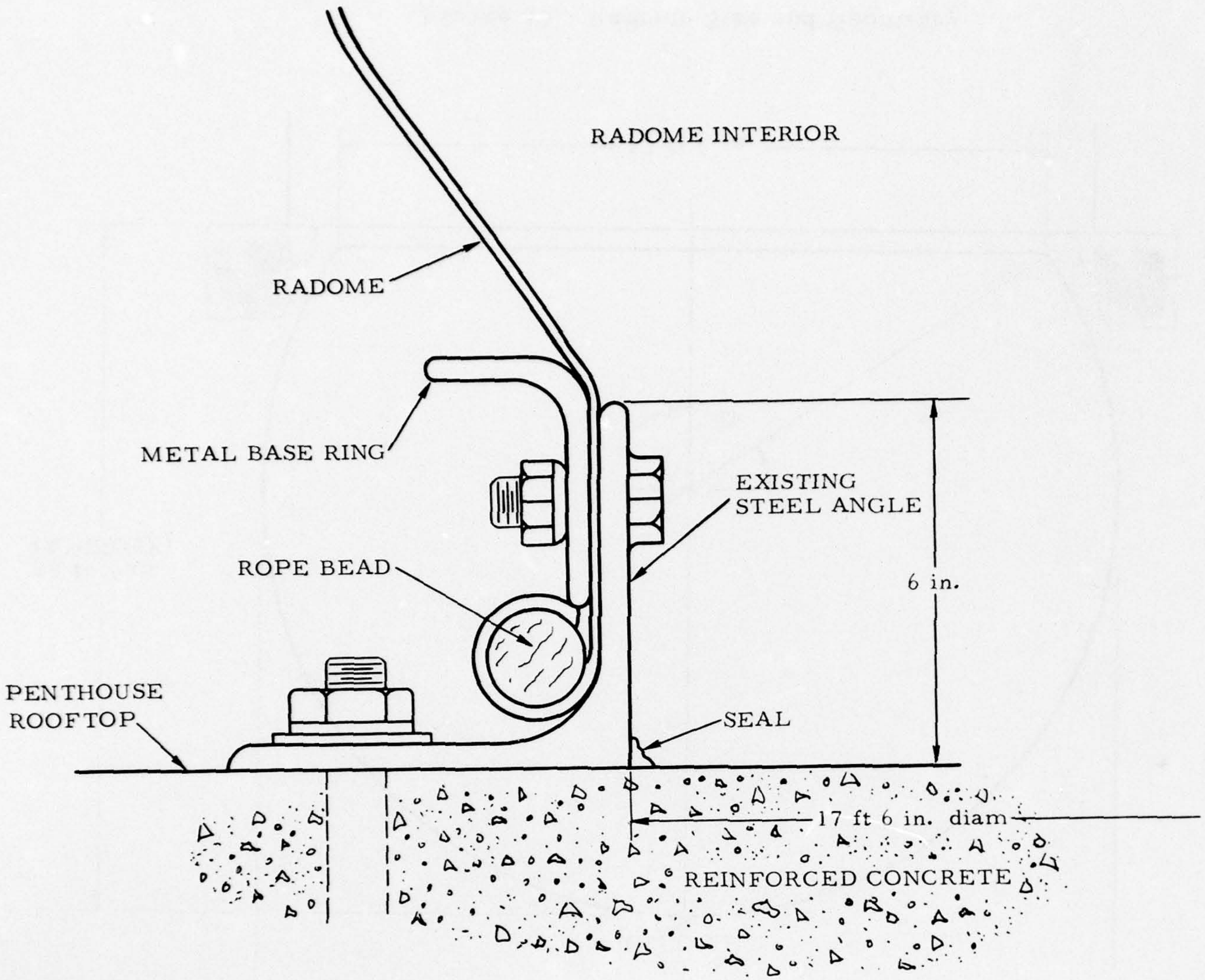


Figure 34. Anchorage of Radome

Material Number	Material Supplier	Description*	Remarks
N5V10	Birdiar	Base fabric of nylon, 5 oz/yd^2 with coating of vinyl 10 oz/yd^2 and polyurethane top coat of .002 inch thickness approximately	Structural integrity marginal
N5V18	Birdiar	Base fabric of nylon 5 oz/yd^2 with coating of vinyl 18 oz/yd^2 and polyrethane top coat of .002-inch thick	
N5V23	Birdair	Base fabric of nylon 5 oz/yd^2 with coating of vinyl 23 oz/yd^2 and polyurethane top coat of .002 inch-thick	
ATVR-22EX	Cidair	Base fabric of 5-1/2 oz/yd^2 with coating of vinyl 23 oz/yd^2 with urethane top coat	Good structural characteristics

*Note there are slight variations in the orientation and/or lamination processes of the various sample materials and direct weight or thickness comparisons should be avoided.

Figure 35. Radome Materials

inserting a sample piece of material in WR28 waveguide and determining the insertion loss and return loss for each material. This method of measurement, although rudimentary, is considered adequate for the purposes of verifying data from other sources and final selection of the Radome material. Insertion loss and return loss measurements for the four sample materials are shown in Figures 36 and 37, respectively. The insertion loss measurements (Figure 36) are indicative of the transmission loss (i.e., it is the total loss and includes reflective and absorptive losses); the return loss curves (Figure 37) are a comparison of the reflective properties of the four materials, and indicate that the major portion of the total loss (i.e., insertion loss) is reflective as would be expected.

In addition to these waveguide-type measurements, a free space measurement was conducted using standard gain horns and a large sample of ATVR-22-EX at 38.0 GHz to determine the insertion loss under rain conditions. The water was applied with an atomizer outside of radiated fields and in all cases wetting did not take place. Since the sample was mounted in a vertical position for testing convenience, the water ran off quickly and the residue remained in beads.

Since the radome is relatively small (i.e., relatively small radius of curvature), it will tend to shed water quickly and the vertical portion tests may be considered to approximate the actual condition.

Under conditions approximating a light misty rain the additional loss due to water was 1.0 dB. Under water spray conditions, where there was a continuous run-off of water, the additional loss due to water was 3.5 dB but recovered within a period of approximately two minutes to a 0.5 dB loss.

Based on these results, it is concluded that the ATVR-22-EX has satisfactory rf characteristics and in view of its good structural characteristics, was selected for use in this application.

PRESSURIZATION SYSTEM

The air inflatable Radome is pressurized by a dual blower system - one online blower and one standby. The basic requirement for the pressurization system is to maintain an internal Radome pressure equal to or greater than the wind pact over the anticipated range of leakage. The dual blower system

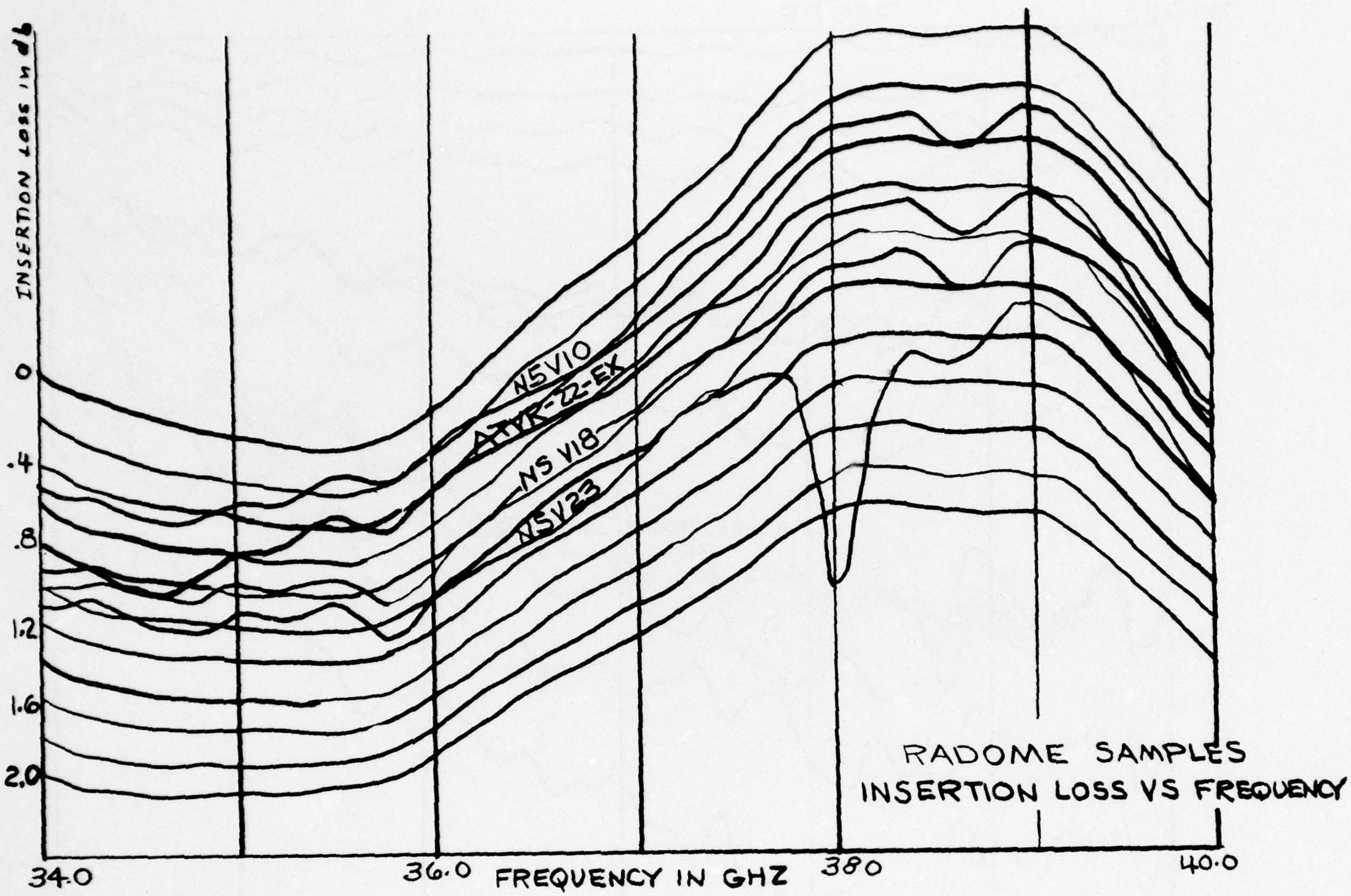


Figure 36. Frequency in GHz

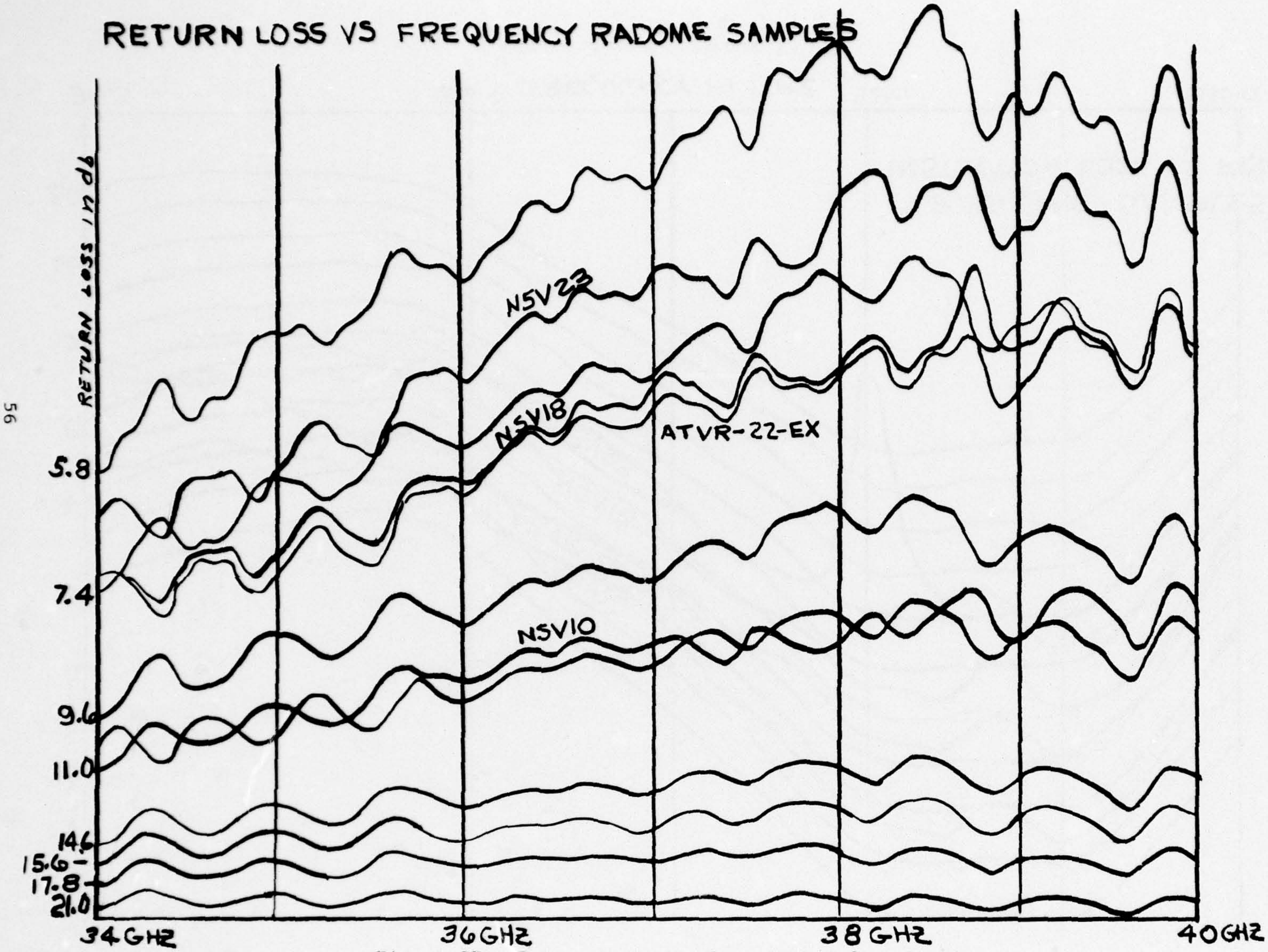


Figure 37. Return Loss vs. Frequency Radome Samples

is set to operate on one blower up to 35 mph winds. When wind velocities reach 35 mph, the secondary blower is activated and remains on-line until winds subside. This operation is automatically activated via the automatic blower control which is housed on the interior south wall of the rooftop enclosure. This Radome control panel permits manual control if desired and displays pressure and blower operation/fault conditions at all times to the Radome personnel.

Location of the inflation blowers is on the rooftop elevator walkway on the west side of the shelter (see Figure 39). Both blowers are mounted to a structural support base and are equipped with isolator damping mounts to reduce vibration transmission and noise. Each blower is equipped with self-adjusting dampers which open and close based on the operation of the blower. These units are located in such a way that it eliminates any possible blockage of the input ports from buildup of dirt or various foreign matter.

The mechanical duct work takes the shortest available path into the interior of the Radome. This path is along the north wall and enters the shelter below the rooftop slab. Entry to the Radome interior is via a 24 inch x 20 inch duct opening in the concrete rooftop slab within the interior of the Radome base ring. Prior to installation of the Radome the pressurization system was tested. The results of this checkout and procedures are as follows:

PRESSURIZATION SYSTEM CHECKOUT
BLOWERS DAYTON #3C073 (See Figure 39)

Block Flow

The duct work output transition on the Rooftop slab (20" x 24") was covered with cardboard and taped secure. A small hole was put in the center and a velometer was attached to measure the output in inches of H_2O. The results are recorded in Table 1.

TABLE 1

Blower On-Line	Inches of H_2O
Primary only	1.6
Secondary only	3.0
Primary and Secondary	3.0

Open Flow

The duct work output transition was measured at various places via the velometer under various conditions to get an average velocity. The results are recorded in Table 2. This test was open flow with no back pressure.

TABLE 2

Blower On-Line	Open Duct Work in Sq. Ft.	Average Velocity FPM	CFM
Primary	2.67	861	2300
Secondary	2.67	1480	3950
Primary and Secondary	2.67	2050	5460

$Q = Va(A)$

Area (A) $20'' \times 24'' = 480''^2$

Duct Open Area = 80%

$$A_{Ft^2} = \frac{480''^2}{144''^2/Ft^2} \times 80\% = 2.67\ Ft^2$$

V_a = Average Velocity in FPM

Q = CFM

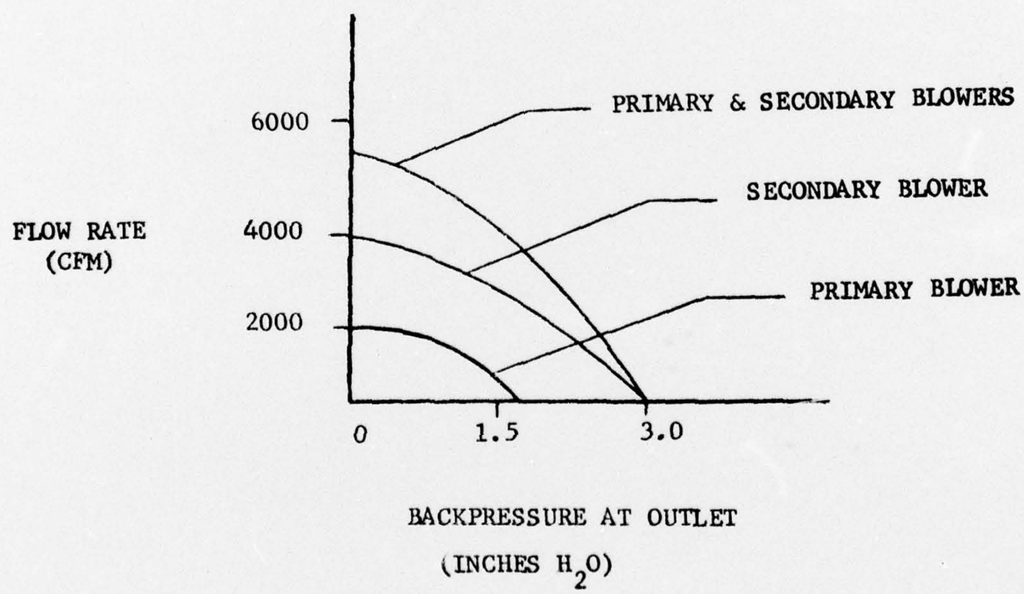
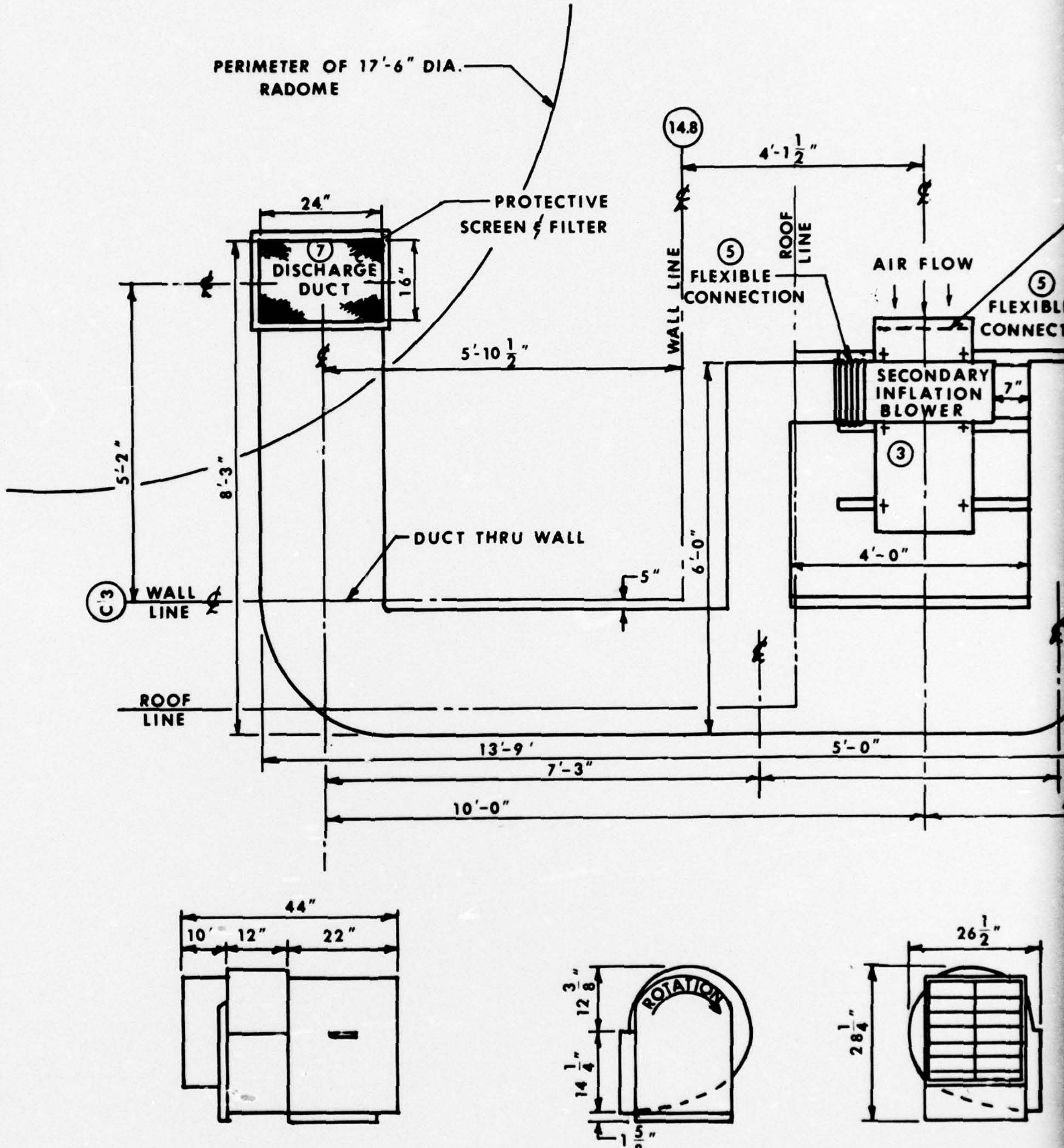


Figure 38. Flow Characteristics



③ INFLATION BLOWER 15"DIA. WHEEL

DAYTON #3C073 W/ WEATHER HOUSING # 3C005

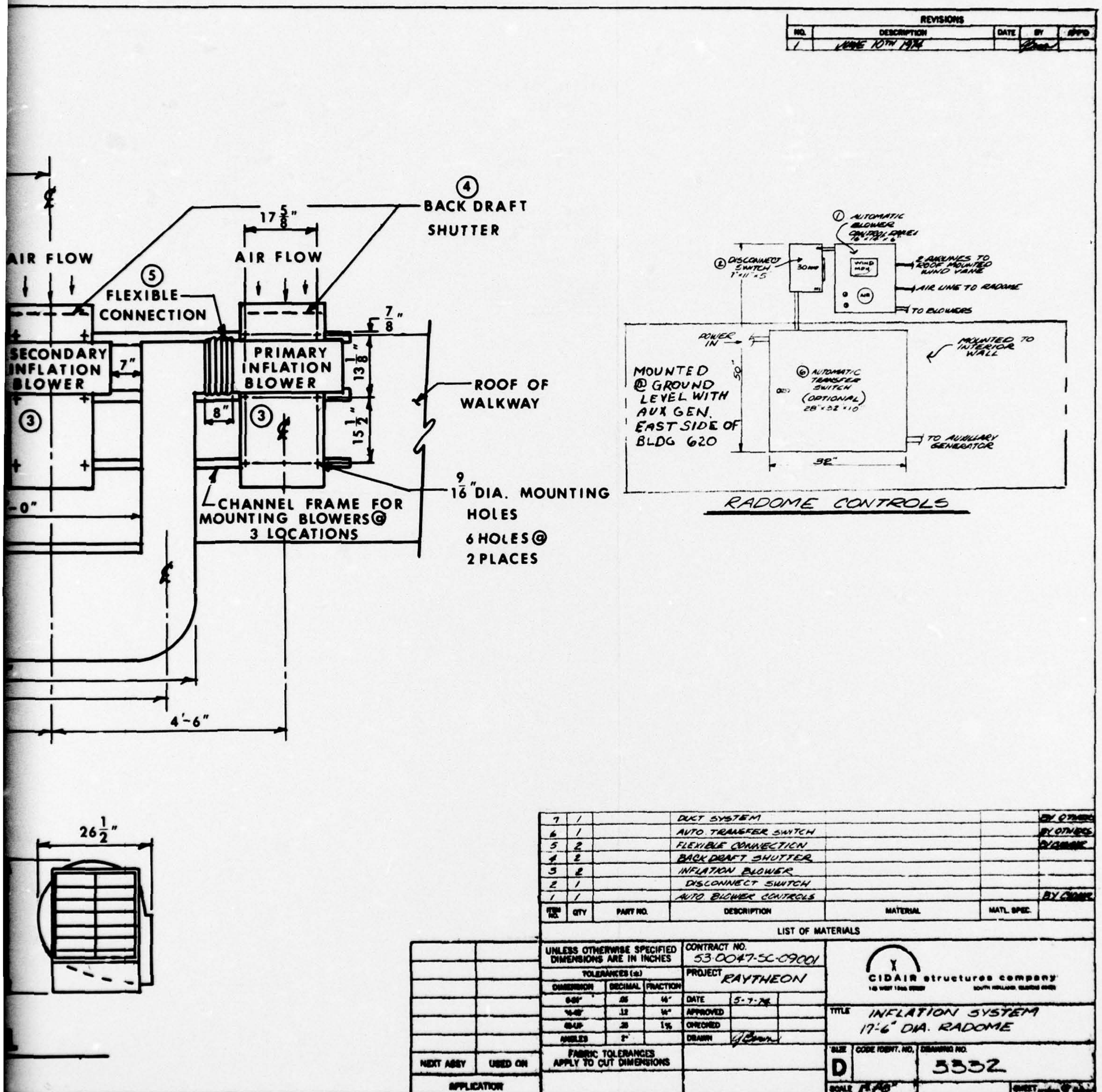


Figure 39. Inflation System 17'-6" Diameter Radome

SECTION 11

AUTOMATIC EMERGENCY GENERATOR SUBSYSTEM

During prime power failures or shutdown, the Rooftop Radome will deflate in a relatively short period of time and be exposed to possible damage to the Radome or Antenna.

Prevention of this occurring has been accomplished by the use of an auxiliary power generator subsystem. This subsystem senses the loss of prime power and automatically activates the auxiliary power generator providing continuous electrical power to the pressurization system.

This auxiliary power generator subsystem consists of:

a. Gasoline engine - generator set rated at 15 kW: 50 Hz, 120/208 volts; 3-phase, 4 wire

b. Automatic transfer/control switch and a weatherproof enclosure

c. Automatic subsystem exercizer

GENERAL SUBSYSTEM FEATURES

Features of the engine-generator are a weather-protective cover, vibration isolators, control box with battery charger, rate ammeter, battery terminals, remote control terminals, reverse current cutout, start/stop switch, and two-step voltage regulator.

AUTOMATIC TRANSFER/CONTROL SWITCH

The Automatic Load Transfer/Control Switch is designed to operate three wire-remote starting electric generating plants having 12-volt battery charging systems. This provides a complete standby power package ready to assume the electrical load during a prime power outage.

The Transfer Control automatically starts the standby generator subsystem on interruption of normal power and transfers the load circuits when the generating plant reaches proper speed and voltage. When normal power is restored,

the control automatically transfers the load back to the prime power and stops the generator subsystem.

Transfer action switch features double coil design, electrically interlocked to provide positive electrically-guided action from "Normal" to "Standby" position. A mechanical interlock acts as an added safety feature against both sources supplying the load simultaneously.

The control system has a trickle battery charger to maintain starting batteries in peak condition. Charge rate is adjustable from 50 to 300 milliamps and includes a milliammeter.

AUTOMATIC SUBSYSTEM EXERCIZER

The exercizer unit automatically starts the generator subsystem at regular intervals and allows it to run for a preset period of time. The length of running time is easily adjusted from within the control unit where it is housed. Length of running time for the generator subsystem may be adjusted from a minimum of 15 minutes once each week to any multiple of 15 minutes as often as desired. The time period adjustment is made by setting the timer housed within the automatic Transfer/Control Switch unit (see Figure 41 and 42).

INSTALLATION

Primarily for safety and ease of maintenance, the Auxiliary Power Generator was located at ground level on the east side of Building 620, as shown in Figure 40. The Automatic Transfer/Control Switch will be installed in a weatherproof enclosure which will be mounted on the east wall of Building 620 (see Figures 41 and 42).

Location of this unit will be within visual distance and close proximity to the generator for purposes of testing the unit and periodic checkouts from the control unit. This location will allow operation of the system without a need to be within Building 620.

Wiring runs from the auxiliary generator to the transfer switch, and from the transfer switch to the automatic blower control located within the rooftop enclosure (see Figure 32). The exact wiring path from the automatic Transfer/Control Switch to the rooftop enclosure is internal within the building cable ducts.

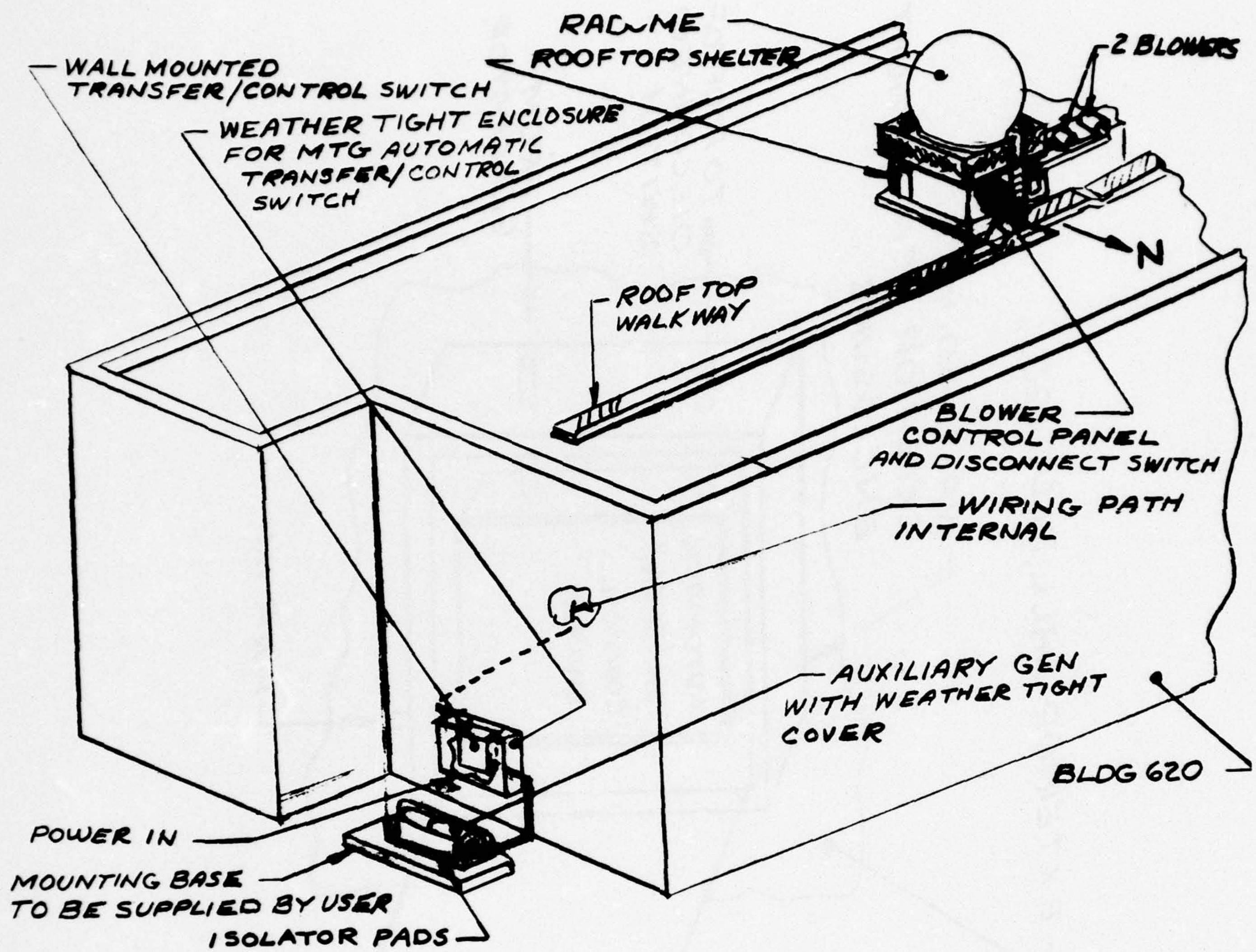


Figure 40. Generator Subsystem

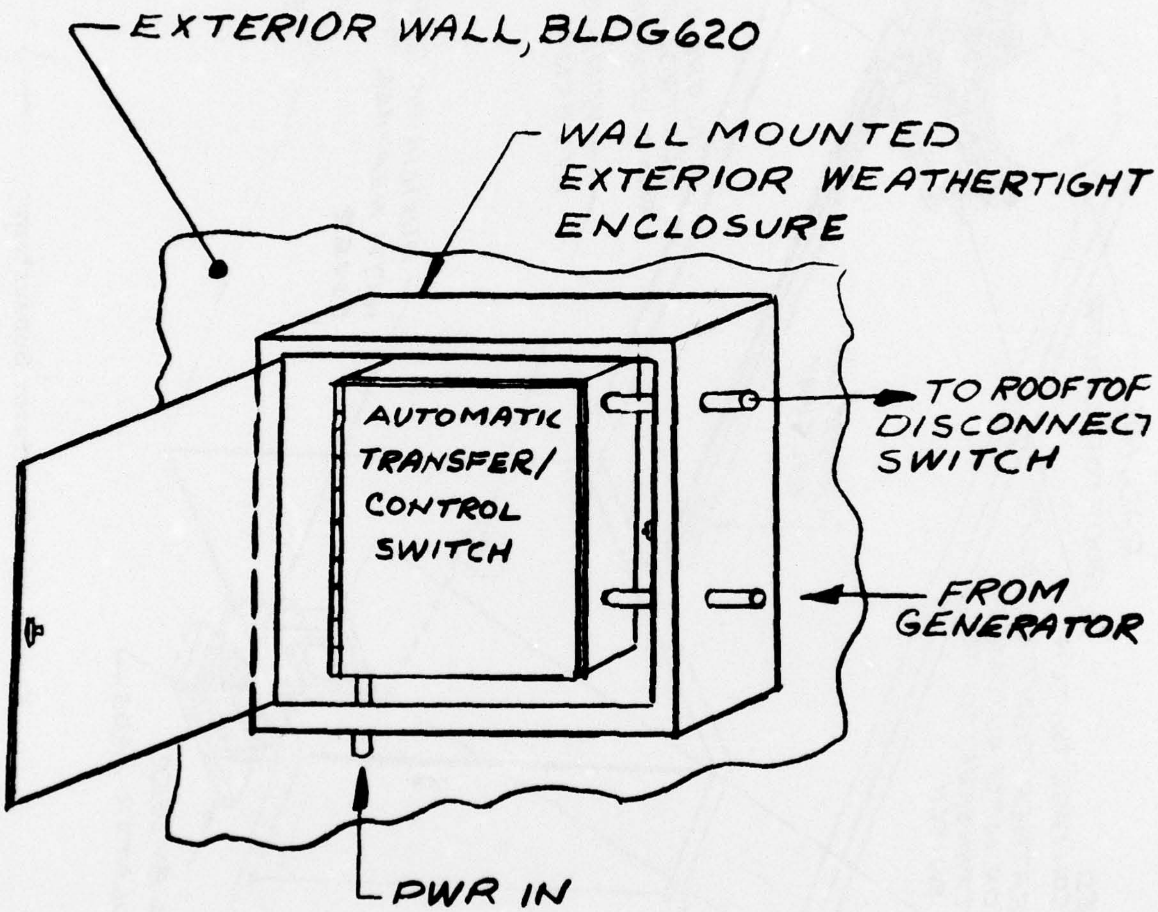


Figure 41. Automatic Transfer/Control Switch Weather-Tight Enclosure

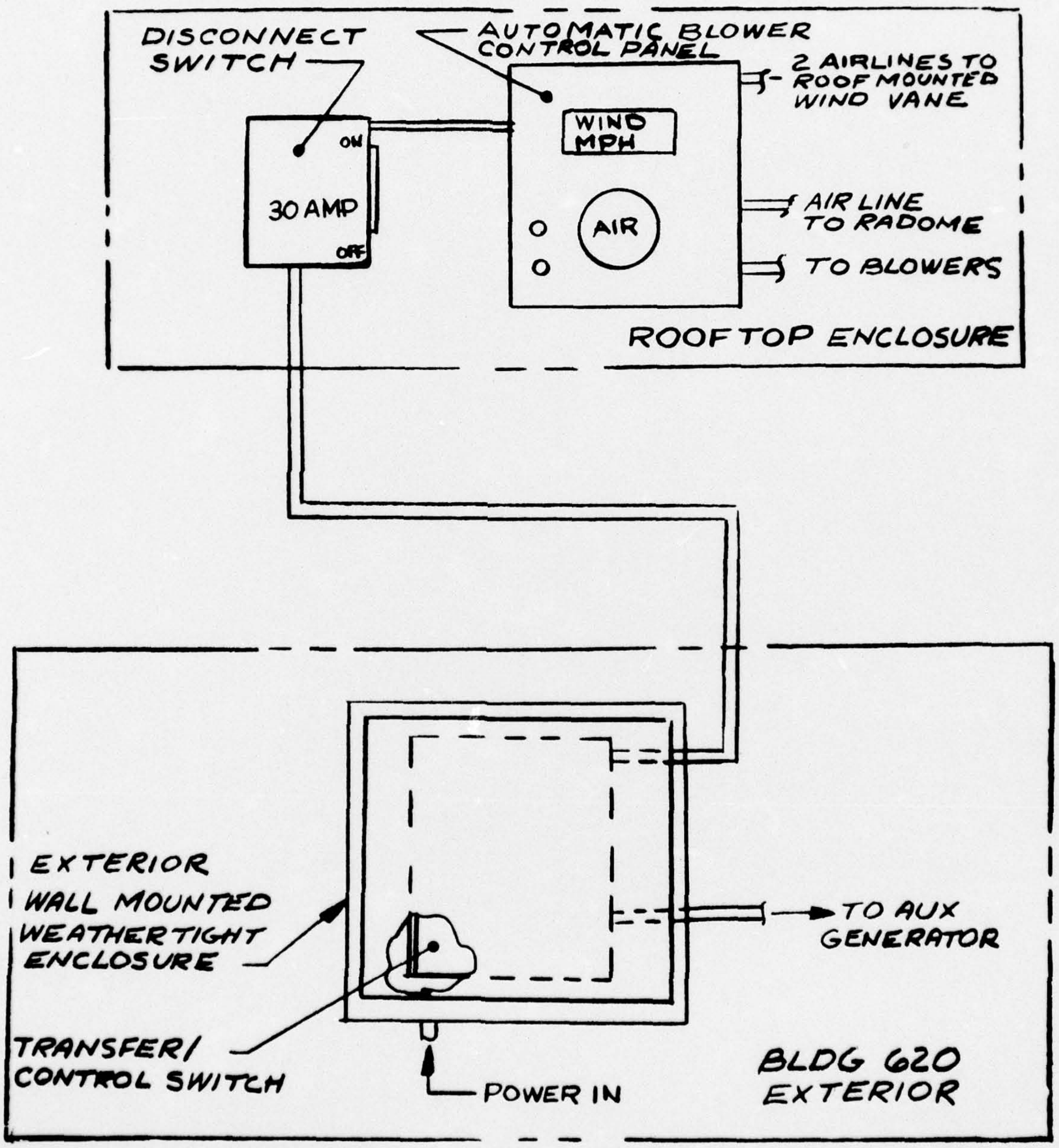


Figure 42. Wiring Path

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977 — 757-001/326